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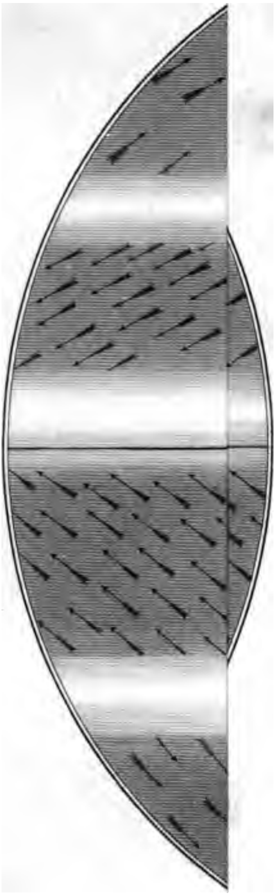
Plate 1.



PHYSICAL GEOGRAPHY

FOR

SCHOOLS AND GENERAL READERS.

BY

M. F. MAURY, LL.D.

COMMANDER IN THE NAVY OF THE CONFEDERATE STATES OF AMERICA:

AUTHOR OF 'THE PHYSICAL GEOGRAPHY OF THE SEA,'
'THE WIND AND CURRENT CHARTS,' 'MAURY'S SAILING DIRECTIONS,'
ETC.

LONDON:
LONGMAN, GREEN, LONGMAN, ROBERTS, & GREEN.
1864.

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198. 9. 7.

LONDON
PRINTED BY SPOTTISWOODE AND CO.
NEW-STREET SQUARE

DEDICATION.

TO

J. M. D. MEIKLEJOHN, M.A.

HEAD MASTER OF ROSE-HILL SCHOOL, BOWDON,

IN TOKEN OF MY ADMIRATION

FOR HIS ACCOMPLISHMENTS AS A SCHOLAR,

AND

HIS RARE POWERS AS A TEACHER AND TRAINER OF YOUTH,

THIS LITTLE VOLUME

IS RESPECTFULLY DEDICATED.

M. F. MAURY.

BOWDON, NEAR MANCHESTER:
June 6, 1864.

PREFACE.

Physical Geography is one of the most useful, instructive, and interesting departments of science.

Every climate of the earth has a Physical Geography peculiar to itself. But the general principles upon which the science is founded are the same for all countries. The object of this little work is to treat of these general principles, and so to present them that the reader may readily apply them to the Physical Geography of his own country.

So far as the sea and atmosphere are concerned as agents in the Physical Geography of our planet, many of the facts and views here presented are derived from original researches by the Author. See Maury's 'Sailing Directions,' 1859; his 'Wind and Current Charts;' 'The Physical Geography of the Sea,' Nelson & Co., Edinburgh; 'The Physical Geography of the Sea and its Meteorology,' Sampson Low & Co., London; 'Nautical Monographs,' and other publications by the Author, while he was in charge of the Washington Observatory.

He is much indebted also to Mrs. Somerville's 'Physical Geography,' to Professor Tyndall's 'Lectures on Heat as a Mode of Motion,' and to Keith Johnston's 'Physical Atlas,' with other standard works of the kind.

London:
June 24, 1864.

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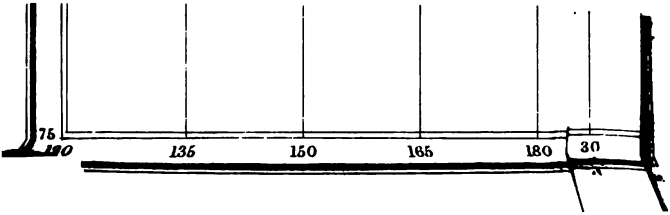
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PHYSICAL GEOGRAPHY.

BOOK I.

§ 1. GEOGRAPHY is divided into two parts—Physical Geography and Political Geography. The population of countries, their boundaries, the manners and customs of the people, their religion, form of government, and all other features and conditions impressed by man upon the surface of the earth—such as cities and towns, farms and edifices, roads and canals—are included under the term Political Geography.

§ 2. PHYSICAL GEOGRAPHY, on the other hand, relates to the earth in its natural aspects, and regardless of the features that have been impressed upon it through man's agency. Physical Geography treats of the plants and animals as they are distributed by nature on the face of the earth; it treats of the phenomena of sea and air, such as winds and currents; of climate; of mountains, plains, and rivers; the distribution of land and water over the surface of the earth; and the like. This little book treats of PHYSICAL GEOGRAPHY.

The first step now is to see how the surface of the earth is divided by nature, and to learn the names of its principal divisions. For this purpose look at a common terrestrial globe; but, if you have no globe convenient, take a map of the world, and you will see that:—

§ 3. The surface of the earth is divided into land and water, and that not much more than one-fourth of this surface is land, the other three-fourths being water. Nearly three times * as much water as land. Remember that.

Each of these two grand divisions has, you will perceive by looking at the map, several well-marked and striking features peculiar to itself; such as large arms of the sea stretching up into the land, long tongues of land jutting out into the sea, bits of land in the middle of the sea, sheets of water in the middle of the land. Let us now learn the names and study how to describe the most striking features of each: and first of the land.

§ 4. The land is divided two ways—that is horizontally, and vertically or OROGRAPHICALLY, as into hills and dales, or mountains and valleys, according as the elevations are greater or less. The Alps, the Andes, the Alleghanies, are mountains. Few parts of the land are so flat as to be without hills. Rome is built on seven hills. Hills are to be seen in every landscape where there is running water to give it charms. The Heights of Fredericksburg are hills. Everybody knows what a hill is: ants and moles make hills.

§ 5. The depressions between hills are sometimes called dales, but whether between hills or mountains they are valleys: as Holborn Valley in London;—the Mississippi Valley in America, which extends from the Alleghanies Mountains on the east to the Rocky Mountains on the west. Every river runs in a valley,

---

* The surface of the earth has an area of 197,000,000 square miles, of which 50,000,000 are known to be land.

as the Valley of the Ganges, the Valley of the Nile, of the Rhine, of the Amazon—which means all the country that is drained by those rivers. Such valleys as those are sometimes called RIVER BASINS or Hydrographic Basins.

§ 6. Horizontally (§ 4) the land is divided into CONTINENTS, of which there are really but two, as the 'Old World and the New;' but for the sake of convenience they are subdivided into *four*—the Old World making three, viz. the continents of Europe, Africa, and Asia; and the New World, or the continent of America, making the fourth.

(*a*) Or into ISLANDS, as Australia, Madagascar, Ireland, Great Britain, Cuba, and innumerable others. Any bit of land, however small, that is entirely surrounded by water is an island; when it is almost surrounded by water it is called a peninsula, or *almost* an island, as Spain and Portugal, Florida, Nova Scotia, Denmark, Malaya, Corea, Kamtschatka, and the like.

(*b*) The minor irregularities or promontories of coast lines are called CAPES, as Cape Finisterre, Cape of Good Hope, Cape Guardafui, Cape Comorin, Cape Horn, Cape St. Roque, Cape Hatteras, and the like.

§ 7. The water is divided also into four grand divisions, called OCEANS, as the Atlantic Ocean, the Pacific Ocean, the Indian Ocean, and the Arctic Ocean; and:—

(*a*) Into SEAS, as the Baltic, the Mediterranean, the Red Sea, the Caspian Sea, the Arabian Sea, the Yellow Sea, the Caribbean Sea, and the like; also—

(*b*) Into GULFS and BAYS, as the Bay of Biscay, the Gulf of Mexico, the Bay of Bengal, the Gulf of Lyons, Hudson's Bay, the Gulf of California, Chesapeake Bay, the Gulf of Carpentaria, Baffin's Bay, the Persian Gulf, and the like; also—

(*c*) Into STRAITS, as the Straits of Gibraltar, the Straits of Babelmandeb, Behring's Straits, Davis' Straits, the Straits of Magellan, the Straits of Florida, the Straits of Sunda, Torres Straits, and the like; and—

(*d*) Into HARBOURS, as the Harbour of Liverpool, of Rio de Janeiro, of Valparaiso. Also—

(*e*) Into LAKES, as the Lakes of Scotland, the Lake of Geneva, Lake Superior, Lake Titicaca in South America, Lake Baikal in Asia, Lake Ladoga in Europe, and Lake Victoria Nyanza in Africa; and finally—

(*f*) Into RIVERS, as the Thames, the Danube, the Volga, the Nile, the Mississippi, the Amazon, and the like.

SUGGESTIONS.

§ 8. Let the young student take any common map of his own country, and be required, without any other but the teacher's assistance, to point out the mountain ranges, the lakes and rivers upon it; and let him tell from recollection of the map where the mountain ranges lie and how the rivers run. Let him also tell where the rivers rise, describe their course, and say where they discharge themselves. This will afford exercise for several lessons.

§ 9. This having been accomplished, place before him a common terrestrial globe, or in default of that any map of the world that happens to be at hand, and let him from that describe the position of each of the four continents (§ 6) and of the four great oceans (§ 7); of the principal seas, viz. the North Sea and the Baltic, the Mediterranean, the Black, the Caspian, the Red, the Arabian, the China Sea, the Sea of Okhotsk and the Caribbean Sea.

§ 10. Of the STRAITS:—The Straits of Gibraltar, Babelmandeb, Malacca and Sunda, of Torres, Behring, and Davis' Straits, of Magellan and Dover.

§ 11. Of the RIVERS:—The Rhine, the Rhone, the Danube, the Dnieper, the Don, the Dwina, and Volga in Europe.

(*a*) Of the Obi, the Yenisei, the Lena, the Amour, the Hoang-ho, and the Yang-tse-kiang, with the Brahmapootra and the Ganges, the Indus, and the Euphrates in Asia.

(*b*) Of the Nile, the Zambese, the Congo, the Niger and the Senegal in Africa: and—

(*c*) In America, of the Mackenzie, the Columbia, and the Rio Grande; of the Saskatchawan, the St. Lawrence, and the Mississippi; the Orinoco, the Amazon, the Tocantins and the La Plata; and—

(*d*) In Australia, the Darling.

§ 12. Observe that none of the islands are large enough to collect and gather into streams rain enough to make very large rivers.

§ 13. Also let him tell where are situated the LAKES Onega and Ladoga in Europe; Balkash and Baikal in Asia; Victoria Nyanza, Tchad and Tanganyika in Africa; and the great American chain from Superior to Ontario, the Great Bear and Great Slave Lakes, Lakes Athabasca and Winnipeg, with the great Salt Lake in North, and Lake Titicaca (also salt) in South America.

§ 14. Next let him describe the position and general direction of the principal mountain ranges, as the Pyrenees, the Alps, the Carpathian, and the Oural Mountains, in Europe.

(*a*) Of the Caucasus, the Himalaya, and the Ghauts, in Asia.

(*b*) Of the Kong Mountains, and the Mountains of the Moon, in Africa; and (*c*) In America, of the Andes, the Rocky Mountains, and the Alleghanies.

§ 15. Also let him tell where the Great Steppes of Asia are, and describe the position of the great deserts both in Africa, Asia; and of Atacama in South America.

§ 16. Also of the following several islands:—the British Islands, Iceland, Newfoundland, Cuba and Hayti in the Atlantic.

(*a*) Of the Japan and Philippine Islands, of Sumatra, Java, Borneo, New Guinea, Australia, and New Zealand, in the Pacific.

(*b*) Of Ceylon and Madagascar in the Indian Ocean.

(*c*) Of Spitzbergen, Nova Zembla, and the Parry Islands in the Arctic Ocean.

§ 17. Having completed these exercises, the pupil will be familiar enough with the grand features of our planet to draw from memory on the black board or on his slate, a map which will represent more or less faithfully the above-named oceans, with their seas, straits, gulfs, bays, and islands; also the continents, with the above-named lakes, rivers, deserts, peninsulas and mountain ranges.

§ 18. Having done this, the pupil will be familiar enough with the general features of the planet on which man has his hearthstone, to begin to study some of the offices which, in the physical economy, have been assigned to these features, and to comprehend some of their most obvious relations to each other. They are parts of a grand and most perfect machine. Propelled by the forces of nature, the office of this machine is to make the earth a dwelling-place fit for man. Consequently it requires sea, earth, and air for the display of its powers—and as the scene of its operations. The true physical geographer looks at the various parts of it, such as we have been describing, as the intelligent young apprentice may be supposed, when he first enters the machine shop, to look at the various parts of the steam-engine which he sees there lying about, but ready to be put together.—There they are, all the various parts, fly-wheel and crank, piston, valve, and rachet, steam chest and boiler. Though they have so little resemblance to each other, and look so little like a compact and powerful machine, yet, when he comes to see them put together, the fires lighted, steam raised, and the engine started, he discovers at once that each part is made to fit into another and work with its fellow,—that the whole is according to *design*, and that every piece has a special office to fulfil, failing in which the whole working of the machine would be thrown into confusion. So it is with the terrestrial machinery, and those features or parts of which we have been describing, and which we have yet to describe. Let us begin, in our poor way, and show how some of these parts are connected together. The next book will treat of some of the offices of the several parts, especially of mountains, hills, and valleys, and show how they are connected with the sea and air.

BOOK II.

§ 19. Let us now, still keeping the globe or the map before us, consider why the surface of the earth (§ 4) is made so uneven; and why the landscape is diversified with hill and dale, mountain and valley; for by that means we may discover at least some of the offices that, in the terrestrial economy, have been assigned to these features of our planet.

§ 20. Suppose the surface of the earth had been a dead level, without a hill to embellish the landscape or a valley to lend it enchantment, there would have been no running brooks, no cooling fountains, no majestic water-courses; where the rain fell, there it would have remained until the winds and the sunbeam could take it up again by the slow process of evaporation, and carry it off; only to be let down upon some other place equally flat, and without drainage. On such an earth the waters never could have been 'gathered together into one place,' the hearthstone for man could not have been laid, our fields would have been one broad marsh incapable of drainage, and the whole land unfit for cultivation.

§ 21. Many and important are the offices which have been assigned to running water. It has to gather from the soil nutriment for the plants, and carry off their refuse; it has to cater among the rocks for food for the insects of the sea. In the physical machinery of our planet, one of the offices of running water is to wear away the rocks and the mountains and carry off the waste or debris to enrich the plains below. It was running water that, in a remote age, collected together the materials of which coals were to be formed, that stored them away in beds, and then piled up above them the washings from the hills, and hid them away in mines for our present and future use. It is difficult to find any habitable part of the earth where running water has not been, and where it has not left its marks. We see them in the marl bed, the gravel pit, and the sand bank; boulders tell of the action of water, and the stratified rocks bear the records of it.

§ 22. Turn to the valley of any river, as the Mississippi for example, and see the vast extent of country to which 'The Father of Waters,' as the American Indians call it, gives drainage, and is able to make fruitful in consequence of this feature of mountain, hill, and valley,—of gradual slopes and gentle descents, in the OROGRAPHY (§ 4) of our planet. All the rain that falls between the Alleghany Mountains on one hand, and the Rocky Mountains on the other, and which is not taken up again by the processes of evaporation, is, by this river and its tributaries, borne off and emptied into the Gulf of Mexico.

§ 23. These hill-sides are the roof, and these streams the gutters, which nature has provided to carry off the rains which fall upon the Western slopes of the one mountain range, and the Eastern declivities of the other.

§ 24. The design of this arrangement will appear still more benign, and striking too, if we contrast it with the attempts by man at artificial drainage. Take that of the City of London as an example for illustration. Here the skill of the best engineers in the world has been invoked, large sums of money have been expended, and the work of drainage is not yet complete. But see what vast areas of country are drained, and what immense volumes of water are carried off by such natural gutters as the Amazon, the Nile, the Ganges, and other rivers, great and small, and that, too, without the cost of a penny to any one.

§ 25. When these highways of nature, as the great rivers may be called, have discharged their waters into the sea, they have not, like the sewers of the city, when they have emptied themselves into the cesspool, performed their offices; sea shells, marl beds, and coral rocks are formed, chiefly of the lime which is gathered by the rains and running waters from the mountains, plains, and valleys, carried, with other salts,* to the sea, and by the currents of the ocean delivered to its inhabitants in due quantity and quality, and at the proper times and places.

§ 26. Of such materials the coral islands and reefs of the Pacific have been constructed. The little creature that does this work is an insect of the sea, called the Coralline. It is not so large as the mite in the cheese. As plants take in their food from the air, so it secretes from the water 'brick and mortar,' as the materials for its edifice may be called. It cannot travel about in search of food, nor send to the marble quarry, or to the beds of limestone rock in the sides of the hill, for materials for its edifices, which are far more stupendous and grand than any ever erected by man, with all his art, skill, and appliances. The currents of the sea bring these to it. Along the coasts of Australia there is a single coral reef a thousand miles in length. Some of the most beautiful and lovely islands in the sea rest on foundations that were laid on the bottom of the ocean, and built up to the surface by these masons.

---

* 'Salts' of the sea: that is all solid matter that has been dissolved from the rocks or the metals, and is held by the sea in solution.

§ 27. Each one is impaled in his own little workshop, and there it is doomed to wait until its food is brought to it by those agents of nature and ministers of the Creator that have been appointed to give them their meat in due season. The obedient waters convey it in never-failing quantities.

§ 28. Limestone, or marble—which is the same thing —is composed chiefly of carbonate of lime. This stone, like gypsum or the sulphate of lime, rain and running water has the property of dissolving, and when so dissolved it is called a salt—a term which, as already explained, is generally applied to all mineral substances, such as earths, rocks, and metals when dissolved in water. Running water has the property of dissolving and carrying off to sea not only lime but many other substances which the inhabitants of the ocean require. For they too, like every other living creature, however small, and every plant, however modest, have their office to fulfil, their task to perform in the physical economy of our planet; they assist to impart to the face of the earth those aspects which it derives from the presence of its flora and its fauna, and which it is the province of physical geography to consider.

§ 29. Of materials thus collected the great whale and all the fish of the sea form their bones; the little diatomes and microscopic insects their shells—five or six millions of which my friend the Astronomer Royal of Edinburgh found in the stomach of a single medusa, or sea-nettle, which forms the whale's chief food.

§ 30. Of materials thus collected by the rains, and brought down from Upper Egypt by the Nile and emptied into the Mediterranean, or from the Falls of Niagara and emptied by the St. Lawrence into the Atlantic, or from the Steppes of Asia and emptied into the Pacific by the great rivers of China, or from the mountains of Peru by the Amazon, do the pearl oysters make their jewels, the sea-conch its shell, and the madripores their ever-green islands, which, in the genial climates of intertropical latitudes, have become the happy homes of many people.

§ 31. Behold now water as one of the most all-pervading, wonderful, and benign agents in the terrestrial economy. But it would be impossible for it to perform many of those offices were there no hills for it to run from, no valleys to run through. This prince of fluids, as marvellous in its properties, in its adaptations, and in the perpetual development of the most beautiful phenomena, as is the fire on the hearth, not only performs the offices that are familiar to us all—and which have almost ceased to be observed, or when observed to surprise, because they are so familiar—of enlivening the earth, pleasing the eye, enchanting the ear, and of assisting the mind to holy thought and meditation; but it does much more, and PHYSICAL GEOGRAPHY presents it in new lights.

§ 32. Now it becomes a solid; and, in passing from the fluid to the solid state it displays a power that forces the rock from the foundations of the mountains, and rends it into fragments or grinds it into sand. Now it becomes a gas, assuming the form of invisible vapour, and carrying off from the sea, water to supply the springs among the mountains that give drink to man and beast; or, spreading itself out as clouds in the sky, it protects the earth from the heat of the sun at one time; or, falling as snow, it covers up at another the young plants as with a mantle, screening them from the biting winds of winter. Fulfilling these duties, it returns again to the beautiful, dancing, laughing water, more enduring than the mountains. It is the only visible thing on earth upon which time, since the world began, has wrought no change. Friction abrades it not, nor have all the keels that have ploughed the ocean wasted so much as one single drop; there it is, pure and bright, just as it came from the hands of its Maker; its powers are unimpaired and ever fresh; it is always busy, and is never weary.

§ 33. Pure water, as it is distilled in the laboratory, is found to consist of two invisible ingredients called oxygen gas and hydrogen gas, united in the proportion of 1 to 8; and in 1,000 grains of sea water, chemists have found of

	Grains.
Pure water	962·0
Chloride of sodium	27·1
„ magnesium . . .	5·4
„ potassium . . .	0·4
Bromide of magnesia . . .	0·1
Sulphate of magnesia . . .	1·2
Sulphate of lime	0.8
Carbonate of lime	0.1
Residuum	2·9=1000

This residuum, consisting probably of iron, silver, copper, silex, iodine, &c.; in short, of something of everything that water or air can corrode, is to be found in the sea, but in quantities too minute for the chemist to detect in his laboratory.

§ 34. That the land should have drainage, and that the rains, after having performed their office on shore, should run off in rivers to the sea with food for its inhabitants, is not the only purpose for which Physical Geography teaches us to believe the mountains were established or the hills made. Man is not able to discover all their uses in the terrestrial economy, but Physical Geography has taught us more than I have yet told you.

§ 35. Mountains promote the formation of clouds, and draw down from them rain to restore again to the rivers what the rivers carry off to the sea. They modify climates also.

§ 36. Take the Andes of South America in illustration, to show how the rains are collected on one side for the Amazon;—how the climate of Peru, on the other side of this mountain range, is made rainless;—and how its peaks, though so near the Equator, are covered with snow all the year round. From them the city of Lima, in the Western plains below, and with a climate of perpetual summer, receives daily its supplies of ice.

§ 37. The prevailing winds throughout all those parts of Brazil and the South American Republics that are drained by the Amazon and its tributaries are from the eastward. They bring the rains and get the vapour for their rains from the Atlantic Ocean. As they ascend that magnificent region of country, they keep dropping down portions of this vapour in showers as they go, and picking it up again, until they reach the mountains. Here the snow-clad mountain tops demand the latent heat that keeps that moisture in the shape of invisible vapour in the air. The heat is delivered up, the vapour is condensed into clouds, which, with the grandest display imaginable, of thunder, storm, and lightning, are precipitated in torrents of rain, hail, or snow.

§ 38. Thus robbed of their moisture, and having no more relays of sea, forest, river, or lake, where they may be furnished with fresh supplies, they pass over these mountain crests and tumble down upon the plains of Western Peru as dry and rainless winds.

§ 39. Now, then, suppose the Andes had been planted along the Eastern instead of the Western shore of South America. These trade winds would have sucked up just as much water from the Atlantic, and brought to the land just as much moisture, as they now do; but instead of dropping it down in gentle showers, and watering as they go, millions of square miles of fruitful plains, they would, as they impinged upon these mountain tops, on first striking the land, have been equally robbed of their moisture; but, instead of dropping it down gently as they go, watering and making fruitful 3,854,000 square miles of country, it would have been poured upon only a few square leagues of land; and instead of descending in showers, as the well-being of plants require, it would have come down with the force of water-spouts and cataracts, uprooting and sweeping away everything before it, and proving more disastrous than the cataclysm of Sheffield, as in the dark night of '64, it swept down the beautiful valley of the Don. In such a case, the Eastern slopes of the Andes would be uninhabitable. So far as the vegetable growth was concerned it would be like watering the plants in a conservatory by emptying bucketfulls upon them, instead of sprinkling them gently through the sieve of the watering-pot. So, you see, that in adjusting the terrestrial machinery the mountains had to be so placed, and the hills so arranged, as to bring down the rain, not only in right quantities, but in the right way also.

§ 40. At Cherraponjie, a mountain station in India, Colonel Sykes observed a rain-fall of 605¼ inches during the south-west monsoon, which blows only half the year. This is at the rate of 86 ft. a year, or more than twice as much during a single month as England gets in the twelve. Cherraponjie is not so close to the sea as we have imagined the Andes in their supposed position to be; nor is it so lofty. The Andes of Peru and Bolivia, as they are, receive no such rain-fall, for the reason that, instead of being within less than 150 miles of the sea, whence the vapour is taken up, and with a flat country for the most part between the coast, as is the case with Cherraponjie, some parts of them are 3,000 miles from the sea that supplies their vapour. Moreover, between them and the sea-shore are numerous minor ranges and high hills, which levy water-tribute from the winds as they pass.

§ 41. We can now imagine some of the consequences that would follow such a derangement in the physical machinery of our planet, if the supposed change were to take place in the position of the Andes by shifting them from the west to the east shores of the continent:—like the desert of Atacama (§ 15) and the plains of Lima, all the country that is now drained by the Amazon and its confluents, and by the upper tributaries of the La Plata, would be a rainless and desert waste, which no living thing could pass save birds of the longest flight.

§ 42. Thus we infer that the climate of every country is not only influenced by its mountains, but it is affected also by their height, their distance from the sea, and the direction in which they lie with regard to the prevailing winds.

§ 43. So much at present for this part of the terrestrial machinery; and while we are getting ready for the examination of other parts, let the student exercise himself in pointing out on the map the basins of the thirty-three rivers (§ 11 *a*, *b*, *c*, and *d*); let him compare the extent of those basins in Europe, Africa, and America that are drained into the Atlantic, with the extent of those in Asia and America that are drained into the Pacific; let him also gauge the area of those basins that are drained into the Indian and Arctic Oceans. He will be struck with the fact that, in comparison with the Pacific, the Atlantic Ocean is a long and narrow channel—that upon the margin of this long and narrow ocean, and upon the waters that are tributary to it, civilisation has its centre, and commerce its greatest marts—and that of all the oceans, therefore, the Atlantic Ocean presents the most busy scenes of commercial activity, and of the industrial pursuits of man. For these reasons it is to him the most interesting.

BOOK III.

§ 44. Allusion has already been made to the winds and to some of the offices which they perform in the operations of the terrestrial machinery; but, before proceeding to examine or explain the part performed by them in making the face of the land to smile and blossom as it does, let us turn for a moment to the atmosphere. It is not only a most important part of the mechanism that we are studying and trying to explain, but it is within itself a most exquisite and powerful machine, now as gentle as the zephyr, now as dreadful as the tempest, and then as grand as the storm.

§ 45. Imagine the earth reduced to the proportions of a peach—the length of its down will represent the height of the atmosphere. But, as we perceive it, enveloping a globe 8,000 miles in diameter, it is really a great ocean covering the earth to the height, it is supposed, of forty-five or fifty miles. It is elastic; it has weight; and it is so very compressible, that three-fourths of it is, by its own pressure, and the superincumbent weight of the other fourth, pressed down and brought below the tops of Kunchinjunga and other high mountains of the Himalaya range.

§ 46. At the level of the sea it presses at the rate of 15 lbs. upon every square inch of surface, or with the weight of one ton for every square foot; and, though its pressure upon the body of each one of us is several thousand pounds, yet, in consequence of a simple law of nature, we feel it not. Nevertheless, the little limpet feels it, and makes use of it too, when he sticks 'so hard' to the rock that you cannot pull him off. By a peculiar faculty he removes the air and water from between him and the rock, and it is then simply by atmospheric pressure that he clings so tightly.

§ 47. The atmosphere, like water, and indeed like a vast majority of all those substances in nature with which we are most familiar, is composed of gases, and like pure water, pure atmospheric air is composed (§ 33) chiefly of two gases; viz. oxygen and nitrogen. Measured according to volume, the proportion is 21 of oxygen to 79 of nitrogen; or by weight, 23 of the former to 77 of the latter. But as the air sweeps over sea and land, it collects and carries with it more or less water in the shape of vapour, and a little carbonic acid gas, which two better adapt it to both animal and vegetable use. Ordinarily in 1,000 parts of common air there are about 4½ parts of aqueous vapour, and a half of carbonic acid.

§ 48. The office of the atmosphere in the physical economy is, like that of the water, all pervading. We have seen in the last book how water conveys to the sea food for the inhabitants thereof, delivering to each its own proper rations in due quantity and at the right time; and how some of these creatures so elaborate this food, re-adapt and prepare it, as to convert it into meat for the whale.

§ 49. So it is with the atmosphere and the treasures with which its breezes are freighted.—It feeds the plants on the land as the waters do the inhabitants of the sea. The leaves suck from the air certain kinds of food which they require; and the air, receiving from the leaves the refuse of that which the plants have used, delivers it to the winds, which bear it away.

§ 50. It is surprising, when we come to analyze a plant or tree, to see how little of the soil upon which it grew has entered into its formation; its stalk, its branches, its leaves, flowers, and fruit, all chiefly consist of materials derived from air and water. They nourish the vegetable kingdom, and upon it the whole animal kingdom rests, either directly, as do our flocks and herds; or indirectly, as does man, who lives on the flesh and milk which those flocks and herds have elaborated from the grass on which they feed. But man and all *bony* animals get the substance out of which their bones are formed chiefly from the plants and fruits of the earth. Every full-grown man requires about four pounds of phosphates to build up his bony skeleton, and that is always wasting away, so he has to repair it continually, and renew it entirely once, it is said, in every seven years; the same with the beasts of the land, the fowls of the air, and the fish of the sea. Imagine, now, the millions and millions of tons of phosphates that have to be collected annually, aye daily, for plant and animal in all parts of the world. To do this is chiefly the work of running water. It searches for these ingredients among the rocks and in the soil; it collects them and brings them to the plants, and they prepare them in their wonderful little laboratories for use in the animal economy. Verily, 'all flesh is grass.' So you see the animal kingdom rests upon the vegetable kingdom, as any other superstructure does upon its foundation. Following out this idea, we behold on the land, as in the sea, chains and dependencies all linked together and connected with air and water as parts of the exquisite machinery of nature—a machinery that, however complicated it may,and does, seem to us, never breaks down and can never go wrong.

§ 51. Chemists tell us, and observation teaches, that with every breath we draw and every fire we light the atmosphere is corrupted. Everything that has breath so corrupts the air which is taken into the lungs that when it is cast forth it is no longer fit for wholesome respiration. Now, if in the physical economy some arrangement had not been provided by which the atmosphere could get rid of these impurities, the whole air would, in the process of bygone ages, have ere this become so tainted as to be no longer suitable for respiration, and man would perish from the earth through lack of wholesome air. In this respect the forces of vegetation come into play and act as compensations, as counterpoises, or checks between the animal and vegetable kingdoms. These kingdoms neutralise the tendency of each other to derange the grand machinery of our planet.

§ 52. The impurities that the animals cast into the air the vegetables absorb, and these again return to the air the very ingredients that the animals require for respiration, or which man needs either for combustion or other purposes in his economy.

§ 53. Now as these impurities, whether coming from the animal or vegetable kingdom, differ from common air in specific gravity, there must be some means provided by nature not only for keeping the atmosphere well stirred up, but also for conveying the impurities away from the places where they are not wanted, and delivering them in those parts where they are wanted, and where they may be taken out. As an example, most of the animals and fires may be corrupting the air in one part of the world—take England in winter, when vegetation is asleep and fires are in most active operation,—

while processes of vegetable growth by which the air so corrupted is to be purified, may be going on in another part of the world—as in the summer of the southern hemisphere, when the flora there is in its greatest vigour; or as in the tropics, where vegetation knows no rest. Taking, then, all these circumstances into consideration, we infer that there must be in the atmosphere a regular system of circulation, else these impurities would all remain where they were received, or, moving about at random, they would meet and all gather together finally into one place, realising the exploded story of the Upas-tree of Java.

§ 54. Not only so, 'All the rivers run into the sea, yet the sea is not full; unto the place from whence the rivers come, thither they return again.'*

§ 55. How do they return? The water from them is pumped up from the sea by the force of evaporation, delivered to the *wayward* winds, as we call them, by them carried through the air, and poured down as rain, to water 'the hills from His chambers,' and send springs into the valleys.

§ 56. Behold, now, not only the Thames, but all the great rivers of the world, as the Rhine, the Nile, the Indus, the St. Lawrence, and the Amazon, rising up out of the sea in thin vapour, and carried by the winds through the upper air, each back to the places in the hill country whence its tributaries flow. These views suggest the probability not only of natural processes for mixing up and purifying the atmosphere, but that, like the sea, the atmosphere also has probably its regular system of circulation.

§ 57. Before, however, proceeding to study the general circulation of the atmosphere, and the direction of the most prevalent winds in the different parts of the world, as exhibited on Plate I., let us explain how the data for this diagram were obtained, for such abundant materials have rarely if ever before been brought together and discussed, touching any subject of physical research.

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* Ecc. chap. i. v. 7.

§ 58. Plate I. was originally constructed at the Washington Observatory, in America. It is copied from Maury's 'Sailing Directions;' with the assistance of a large corps of officers, the author of this little book was there employed from the summer of 1842 to the spring of 1861, in collecting and collating, for the benefit of navigation, observations concerning the winds and currents of the sea. These were obtained in all parts of the world by navigators who, as they passed to and fro on the great deep, recorded three times a day in their log-books, for his use, the force and direction of the winds, with the readings of the barometer, thermometer, &c. Each observation included a period of eight hours, and the number used for this plate alone was 1,259,353. This plate, therefore, represents from the most abundant data ever obtained, the general movements of the air at sea, and the prevailing direction of the wind on its surface as recorded by mariners in their log-books, except in the monsoon regions; and for them it gives the prevailing direction for at least one-half the year. On and near the land, the direction as shown on the Plate is often changed, but never so much, except in the monsoon regions, as to be reversed. Indeed if we divide the compass into halves, instead of, as it is done on the Plate, into quarters and points, we are safe in laying this down as a general rule applicable to both sea and land:—In all latitudes between the parallel of 30° or 35° N. and the parallel of 30° or 35° S., the prevailing direction of the wind is from the *eastward*; in all other parts of the world, as far as observation has gone, it is from the *westward*. This rule applies to all parts of the world, from the Arctic to the Antarctic regions, except, as before stated, to the monsoon regions. These exceptions will be explained when we come to the monsoons.

§ 59. The observations thus collected became so valuable for the information that they afforded, and by which sea voyages were shortened and their safety increased, that finally, in 1853, a conference was held at Brussels, at which the principal maritime nations participated. The consequence was, a general plan of cooperation and research for investigating the phenomena of sea and air was proposed; in which the powers represented agreed to co-operate. This led to the establishment of the Meteorological Department of the Board of Trade in London, over which Admiral Fitz Roy presides so usefully. Also to others in Holland, France, Portugal, and elsewhere. But unfortunately, this beautiful and useful system of research has been sadly interfered with by the American war.

§ 60. Turning now to Plate I., it may be taken to represent any half of the earth's surface bisected by the equator. The arrows are supposed to fly with the wind; they represent simply the prevailing direction of the wind, and the longer the arrow the more prevalent the wind represented. Thus you observe that the arrows between the calms of Capricorn and the belt of equatorial calms are longer than the arrows to the North, or on the *Polar side* of the calms of Cancer. The meaning of this is, that the SE. Trade winds, which the longer arrows represent, blow for more days during the year than do the counter Trades, or the SW. winds, which the shorter arrows represent.

§ 61. Observations have shown that the mean height of the barometer is greater near the calm belts of Cancer and Capricorn than it is at the Equator, or than it is near the Poles; and that in the Antarctic regions, the mean height of the barometer is less than 29 inches; whereas in the Arctic regions, say in lat. 78°, it is nearly an inch higher; and furthermore, it will be observed, that the winds are blowing from the tropical calm belts where the barometer is high, both towards the north and the south, and in each case towards the place where the barometer is low. This is the case in both hemispheres. In the northern, we have on one side of the calms of Cancer, the NE. Trade winds blowing towards the belt of equatorial calms with its low barometer, and on the other side we have the *counter* Trades, or south-westerly winds, blowing towards the low barometer of the Arctic regions.

§ 62. So likewise in the south hemisphere, we have the SE. Trade winds on one side of the calm belt of Capricorn blowing towards the Equator, and the counter Trades or north-westerly winds of the Polar side blowing *towards* the *Antarctic* regions with their low barometer.

§ 63. From these facts we draw a conclusion and deduce a law of great importance both to the meteorologist and physical geographer. The first is,—as the barometer measures weight, we infer that where it stands high there is a greater accumulation of air over head than there is where it stands low, and that consequently, as the natural tendency of air is to go from the place where there is a surplusage to the place where there is a deficiency, we have this general law:—

§ 64. The wind will always blow from the place of a high towards the nearest place of low barometer.

§ 65. It is in obedience to this law, that the Trade winds in each hemisphere blow towards the equatorial calm belt, and it is in recognition of this law that the mariner and meteorologist say, 'The barometer is low, and falling; look out for a storm;' or 'The barometer has begun to rise, or is high; we shall have fine weather.'

§ 66. Why, let us enquire, should the equatorial calm belt be the place of a low, and the tropical calm belts places of a high barometer?

First as to the former question:—

§ 67. The equatorial calm belt is a region of constant precipitation. Into it the air brought by both systems of Trade winds is emptied. This air, coming over the sea, is loaded with vapour. Vapour is lighter than air; and aqueous vapour contains an immense amount of latent heat, which, when the vapour is condensed, is set free and becomes sensible heat. Now the NE. Trade winds pressing this calm belt on one side, and the SE. on the other, force this vapour-laden air that they pour into the calm belt, to rise up, and so give place for that which is pressing on behind it; as it rises, it expands; as it expands, it cools; being thus made cooler, it takes from the vapour its latent heat, converting the vapour first into cloud and then into rain; as this latent heat is liberated it becomes sensible heat; as such it warms the air, thereby expanding it, making it still lighter, and causing it to ascend still higher, and so compelling it to give room for the inflowing Trade winds below.

§ 68. As this warmed air rises up and gets higher, it flows off as an upper current. It is supposed so to flow by the mere force of gravitation, for it is conjectured that if we could see the top of the atmosphere above this equatorial calm belt it would appear very much bulged out, and be seen protruding above the general level of the atmosphere. Though higher than the atmosphere on either side of this cloud-ring, it does not press so heavily on the barometer below it, for the simple reason that being thinner and lighter there is not so much of it over-head there as there is over-head in the tropical calm belts, where the air is drier, cooler, and heavier, and consequently more compact.

§ 69. Under these two calm belts there is comparatively little rain. The countries between the parallels of 30° and 40° in Europe, Africa, Asia, and America, in which the rains are scanty or unknown, are within the range of the calm belt of Cancer, and the air within this calm belt is for the most part dry air. Therefore as this belt of Cancer, with the whole system of Trade winds and calm belts, moves up and down the earth after the sun in declination, it brings to all the places within its range their seasons of drought.

§ 70. It will also be observed that while the Trade winds are travelling towards the Equator, they are also going to the westward: this westward tendency, also indicated by the arrows, is due to the effect of the diurnal rotation of the earth on its axis, and is explained thus:—

§ 71. If the earth stood still and did not revolve on its axis, the Trade winds would blow, the one North the other South, directly towards the Equator. But the earth revolves from West to East, making one complete revolution every 24 hours, and, as a girth round the globe, near one of the tropical calm belts, where the Trade winds commence, is not so large as it is near the Equator, where they end; they are consequently being whirled round the axis with greater velocity near the Equator than they were when near the tropic, just as a fly on the tire of a coach-wheel is whirled around with greater velocity than his fellow on the hub. Wherefore, as these winds approach the Equator, they feel the earth slipping from under them as it were; this lagging behind gives them their westwardly direction, making it appear as though they came from the NE. on one side, and from the SE. on the other side of the Equator. Conversely and for a like reason, the counter Trades, or those which blow towards the Poles, appear to come from the opposite direction. They are coming from parallels of greater girth, or where the velocity of diurnal rotation is greater, and going to parallels of less girth, and with less velocity of rotation; consequently they are travelling to the eastward faster than the parallels at which they successively arrive, and they appear to come from the westward.

§ 72. Whereas, if the earth stood still, they would blow directly towards the Poles, so that the particular direction of the wind in each of these grand systems is determined by a simple mechanical law which relates to the composition and revolution of forces.

§ 73. We turn now to the difference between the Arctic and Antarctic barometer.

§ 74. A glance at the globe, or a map of the world, shows that from the parallel of 40° North to far within the Arctic circle it is nearly all land; whereas, from the corresponding parallel South to the Antarctic regions, it is nearly all water.

§ 75. Consequently the winds in this part of the Southern hemisphere, while sweeping over such a waste of waters, become charged with vapour, which, being lighter than air (§ 67), drives portions of the air off, taking its place; when this vapour is condensed into snow, hail, or rain, it sets free a vast amount of heat in the upper regions; this heat warms and rarifies the air still more, causing it to rise still higher, and the barometer to fall still lower.

§ 76. The better to appreciate the influence of so much vapour in lessening the barometric pressure, let us remember that three-fourths of the atmosphere (§ 45) are within about 5 miles of the earth;—that if we remove 1,000 pounds of dry air, and fill with vapour the space which the dry air occupied, the vapour will weigh only 623 pounds—that is, a measure that will hold 100 lbs. of vapour will hold 160½ lbs. of dry air. In other words, dry air is 60·5 per cent. heavier than vapour. Now imagine a very long tube standing on the level of the sea, and reaching the height of five miles; suppose all the air be pumped out of it, and that then it be filled with vapour; suppose, also, it has a barometer on the inside standing on the bottom, and another at the same level on the outside, both of which can be read at the same time;—when the barometer on the outside shows a pressure of 30 inches, that on the inside would show a pressure of only 21½ inches. Now, if we imagine a portion of this vapour to be condensed, the heat that is liberated will expand and drive off a part of what is left, still keeping the tube full, and so the barometer in the tube will fall still lower. Hence we deduce a rule:

§ 77. That in the regions of constant precipitation, as under the equatorial cloud-ring, and in circum-Antarctic latitudes, where the air is loaded with moisture, the barometer stands low for two reasons:—one being, because the vapour is lighter than the air, portions of which it displaces; and the other, because the heat evolved in the processes of precipitation warms and expands, and makes still lighter the air which remains.

§ 78. Allusion has been frequently made to the latent heat of vapour. It has a great influence upon winds and upon climates. To it and the Gulf Stream, but mainly to it, the British Islands, Norway, and the whole of Western Europe, are indebted for the mildness of their winter climate. Labrador and the United Kingdom are between the same parallels of latitude; to both the prevailing winds are from the westward. But in Labrador the winds are Continental: they come from the land and are dry. In England and Scotland they are marine: they come from the sea and are moist; and the heat that is set free by this moisture, when it is formed into clouds or condensed into rain, so modifies the climate as to make green pastures here in winter, whereas in Labrador, everything is fast bound in ice for eight or nine months during the year, and the winter there is so severe as to make the country almost uninhabitable. Nor need this be surprising, when you remember that when vapour enough is condensed in the sky to make one gallon of rain-water, heat enough has been liberated in the cloud-region to raise the temperature of 5⅔ gallons of water from the freezing to the boiling point. This heat is sufficient to temper thousands of such measures of air, for common air has nothing like—no not the 3,000th part—the capacity for heat that water and vapour have.

§ 79. Having seen how the low barometer in the Antarctic regions is created by the excessive moisture in the atmosphere, and by the constant precipitation there, we can readily understand why, in the Arctic regions, these conditions being absent, we should have the barometer comparatively high. There the prevailing winds (§ 72) are from the westward. They for the most part blow over the land. They are, consequently, comparatively dry winds. And, as dry air is heavier than moist, the barometer ought to stand higher under the clear blue skies of the Arctic than it does under the dull leaden clouds of the Antarctic regions.

§ 80. We may now sum up the whole matter of this book:—1. A low barometer near the Equator, and a belt of calms; a high barometer with a belt of calms near each tropic; and again, a low barometer in the circum-Polar latitudes, both North and South. And 2. From these two places of high barometer, there is a general tendency of the air to flow both North and South towards the places of low barometer; and the direction of the currents in their tendency so to flow is controlled by the influence of diurnal rotation.

§ 81. Such are the general movements of the grand atmospheric machine that compasses the earth; such also are its operations and movements.

BOOK IV.

§ 82. We are now prepared to take special notice of the following facts, and to make a note of them: viz. the Northern hemisphere has most land and most atmosphere, and the Southern most water; though meteorologists tell us that the hemisphere with the most water has the least rain. This is a curious and suggestive fact, and I wish you to make a note of it, for it will be referred to again as a key to other knowledge. If our hemisphere be blessed with the most bountiful rains, it is also richer in daylight, for the sun in his annual round tarries on the north side of the Equator 7¾ days longer than he does on the south side of it.

§ 83. The total amount of heat annually impressed by the sun upon the earth is a constant; and, since the surface of the sea is not supposed to vary materially in its superficial area from one year to another, the total amount of evaporation that annually takes place from it, as well as the total annual rain-fall throughout the world, may also be taken nearly as constants: at any rate, they are reciprocals.

§ 84. The machinery which we are studying derives its motive power chiefly from the solar ray; for it is the sunbeam which gives circulation to the atmosphere, wings to the wind, and motion to the sea; the solar ray imparts life to the plants and fleetness to animals; it pumps up from the sea showers for the earth and water for all the great rivers of the world; it loads the wind with the treasures of the hail; and it has been calculated that it impresses daily upon the earth heat enough to melt a layer of ice all over sea and land, to the thickness of three inches and a quarter.

§ 85. Since it is not known that the earth is growing cooler or warmer from one year to another, it may be asked, what becomes of this heat? For, like that heat which drives the steam engine, though lost to man, it is not to nature. As the matter of which the world is made cannot be annihilated, neither can the heat of the sun be lost; it simply, after it has performed its office in the terrestrial economy, slips away and disappears from human ken, like the heat from the furnace. Having fulfilled its manifold offices, it is still obedient to the forces of Radiation; propelled by these, it passes away from the earth and enters the realms of space.

§ 86. Let me explain what RADIATION is. Most, indeed I believe all, bodies have two ways of getting cool; one is by *Conduction* often assisted by *Convection*: that is, a heated body gets cool by imparting its heat simply to the objects with which it happens to be in contact. And this process of cooling is assisted by these surrounding objects, if any of them happen to be fluids or gases, as air and water; for the particles of air and water, as soon as they receive heat by conduction, are expanded and made to rise up or run off with it; and thus they convey it away by *convection*. The other process is by the heated body sending certain portions of its heat off into space, without this heat affecting the temperature of the air through which it passes. This is by RADIATION. The red-hot poker plunged into a stream of running water imparts its heat to the water by *conduction*, and then the water carries it away by *convection*; so that when conduction is assisted by *convection*, the process of cooling is more rapid. On the other hand, the earth grows cool at night, especially in a clear and calm night, by radiation: that is, by not warming the air by which it is surrounded as the poker did the water, but by sending the heat off through the air into space, as the sun or the fire sends rays through certain kinds of glass without heating the glass.

§ 87. The earth radiates heat by day as well as by night; but it cannot radiate heat in a summer's day as fast as the sun imparts it; it can only do this about half as fast. So that, in the spring and summer, not being able to radiate off during the day and night, quite all that the sun sends down during the day, there is a gradual accumulation of heat in the crust of the earth, until August or September. In autumn the heat of the sun becomes less powerful. At this season, we in England cease to get as much of it; the earth now radiates more than it receives; consequently the earth begins to get rid of its old store of heat faster than the sun can supply it with more. In this way—and as the nights grow long, the days short, and the rays of the sun wax feeble—the earth gets rid of more and more of the heat that has been accumulating during the summer, growing cooler and cooler until the power of the sun gets strong again, which is after the winter is passed and gone. Thus winter and summer are established.

§ 88. By the process of radiation, the night also is made cooler than the day, and dew is formed. As soon as the sun goes down, the plants and grass and every thing else begin to send off their heat and grow cool, especially if the sky be clear; for clouds interfere with radiation. As the grass and other objects grow cool, they, by conduction, rob of its latent heat the vapour that is floating in the air, for the air is never without some vapour. Being deprived of its heat, this vapour then resolves itself into water; and, in the shape of dew, deposits itself on the grass precisely as moisture deposits itself on the outside of a pitcher of ice water.

§ 89. Now, were it not for this invisible vapour that is, even in the clearest days, floating in the air, the whole surface of the land would be parched by day—even in these latitudes—like the desert, while at the Equator it would, by night, be bitten with severe frost. According to Tyndall, these invisible particles are so many shields to defend the earth from the heat of the sun, and to protect the green herb from being scorched by day and frozen by night. They literally shiver and splinter the sun's rays as they come darting down through the air. They protect the earth against the fierce intensity of the sun, and when he gains a lodgment on the earth's crust for a portion of his heat, they prevent its too sudden escape again, and so the invisible vapour in the air controls the sun by regulating the forces of the sunbeam.

§ 90. The land and sea breezes tell us in their mute way, that the land radiates heat more freely than the water or the air. Along the sea coast in all countries, when the sun is shining and the days are hot, there is a breeze from the sea by day, alternating with a breeze from the land by night. These are the land and sea breezes. They are explained in this way:—In the day, the land becomes heated by the sun to such an extent, that the air in contact with it becomes so rarified as to ascend, and the cool fresh air of the sea comes rushing in, as a delightful breeze, to restore the equilibrium. At night, the land radiating more freely, becomes cooler than the sea, and then the cooler and heavier air from the land rushes out to displace the now warmer air over the sea. This is the land breeze.

Thus we see already, that we have wheels within wheels in our atmospherical machine, all tending more or less to divert the wind from his circuits, to influence climates, or to modify the rules laid down in Book III. as to the general circulation of the atmosphere.

I therefore proceed to fulfil the promise of § 44, and to show how the winds in their manifold offices, help to make the face of the land as beautiful as it is, and also how they influence climates; for climate is an affair of moisture as well as of temperature.

§ 91. Moisture is distributed over the surface of the earth by the winds. They get it from the water. Moisture and winds are mighty agents in Physical Geography, for whether such and such climates are suited to the growth of this or that plant, depends in no small degree upon the early and the latter rain, and upon the rain in due season. And consequently, whether this or that climate be adapted to the well-being of any particular animal, depends upon the suitableness of the climate for the production of the food required by such animal. The fig and the orange tree, the rice plant and the sugar cane will not grow in the frozen regions of the north; neither can the insects, the birds, or the beasts which feed upon these plants or live upon their fruits flourish there.

§ 92. Allusion has been made (§ 78) to the wonderful capacity of water for heat. By the presence of heat in greater or less quantities—for *some* heat is always present even in the coldest bodies—water is made to assume its various shapes. Whether this crystal fluid be now gaseous, now liquid, or now solid, is all a mere question of heat. In every shape, it is an important agent of nature; for in the solid state as ice, it is employed to cleave, split and pound; in the liquid state, to fetch and carry; and as vapour, or in the gaseous state, to distribute heat as well as moisture over the surface of our planet. The average rainfall in Great Britain is about thirty-six inches; the area of the island is about 87,000 square miles. Now, in a rain which should give a fall of one inch for the whole island, the volume of heat set free over head would be more than would be evolved by the combustion of three hundred and fifty million tons of the best coal—more than four times the quantity that all the mines of Great Britain yield annually—and yet the evolution of heat in such inconceivable quantities is an operation that takes place on the average three times a month, and we observe it not.

§ 93. In this our study of the operations of this wonderful machinery, the question may be asked: Where does this heat come from?—It comes first of all from the sun; then, from those parts of the sea, wherever they be, whence the vapour for this rain was taken up. It may have been taken up from inter-tropical waters; it may have come from the Great South Sea; or it may have been, and a part at least no doubt was, furnished by the Gulf stream. But be the vapour-springs for our rain where they may, the surplus heat in some distant parts of the sea is gently absorbed by vapour, bottled away and rendered *latent*:—that is, concealed in the little vesicles of this invisible contrivance. It is then conveyed here by the winds, and set free during the process of condensation, in volumes so immense that the mind cannot comprehend them; and yet in a manner so gentle, and at times and in places so arranged, that habitually we perceive it not.

§ 94. The law is, as before stated (§ 78), that when vapour enough is condensed to make one gallon of rain-water, heat enough is set free in the clouds to raise 5⅔ gallons from the freezing to the boiling point:—that is, if you put a vessel containing a gallon of water on the fire and boil the water away, i.e. convert it into steam, all the heat which it took to boil it away will be set free, and reappear when that steam is condensed into water again.

§ 95. If the vapour, when so condensed, be frozen into hail or snow, there is a farther liberation or developement of heat, which is enough for every gallon of water so condensed and converted into snow or hail, to raise ¾ of a gallon from 32°, the freezing point, to 212°, the boiling point. Hence, when vapour enough for a gallon of water is condensed in the sky and formed into hail or snow, heat enough is set free in the air to raise the temperature of 6½ gallons of water from 32° to 212°. And, since the capacity of water for heat exceeds that of air, volume for volume, 3,080 times, it follows that in the process of condensing the vapour for this one gallon of water, and of freezing it into hailstones, heat enough is liberated in the cloud region to raise *sixty-seven thousand six hundred and ninety* gallons of air from the temperature of melting ice to summer heat. It is in consequence of this immense discharge of heat for a summer's hailstorm, that the country people on the Continent and in America are heard to remark, 'the weather is so oppressively warm, we are going to have a hailstorm.' And during the afternoon the hail is almost sure to come, attended by violent gusts of wind.

§ 96. With such sources of heat overhead, it is not surprising that Mr. Glaisher should report that in one of *his winter* balloon ascents, he passed, away up in the cloud-region, through a stratum of warm air 3,000 feet thick. That air had been made warm by the heat which had recently been liberated in the process of condensing vapour into clouds, rain or snow. It is a curious, benign, and wonderful arrangement; and, before proceeding further with the study of this exquisite machinery, it is necessary to explain a little more about these thermal reservoirs in the sky; for there are reservoirs of cold there as well as of heat; and the weather to-morrow may be much colder or warmer than the weather to-day; for such changes depend in a great measure whether the air from one of these cold or hot reservoirs shall be brought down to us or not.

§ 97. It is a law of nature that the temperature of all bodies shall be increased by compression, and diminished by expansion. It is under this law that the smith, by merely placing on the anvil a cold rod of iron, and hammering it, makes the point red hot, and so lights his fire. It is by this law that the chemist, by suddenly forcing the closely-fitting piston down into his little air-filled cylinder, will ignite a bit of tinder at the bottom of it. This is done merely by compressing the air quickly, and forcing, so to speak, the latent heat out of it, thus compelling it to take the form of sensible heat, and to develop itself in the shape of fire. Now, if by some of those multiplied and complicated movements which are always going on in the atmosphere, both vertically and horizontally, Glaisher's layers of warm air—he found one at the height of 8,000 feet actually warmer than at the surface—had been brought down to the surface, it would have been compressed by the addition of superincumbent weight alone, like the chemist's air in the cylinder, only more gently, and not so much; for, instead of being scorching or burning hot, it would simply have been made about 27° warmer by the gently increased pressure. This would have made a change in the weather, and might have given us a hot day in April.

§ 98. In the case of ascending air, the reverse takes place. At the surface of the earth, the pressure of the atmosphere is, you remember (§ 46), 15 lbs. upon every square inch; and $\frac{3}{4}$ of this pressure, or about $11\frac{1}{4}$ pounds, is made by that portion of the atmosphere which is between the surface of the earth and the tops of the highest mountains; consequently, if we were to send a bit of atmosphere from the sea level to the mountain top—which we might do in an india-rubber bag or foot-ball—we can imagine that as so much pressure would be taken off, it would expand very much, and in expanding, cool. This is the reason why greatly-elevated places are always so cold, and why high mountains, even in the Torrid Zone, are everlastingly capped with snow. The rule is, that as you ascend from the sea level, the temperature *de*creases ordinarily and on the average about one degree for every 100 yds. that the thermometer is carried up perpendicularly, and that the temperature increases about one degree for every 60 feet that you descend into the bowels of the earth; so that, at the depth of 25 or 30 miles below the spot on which you are now standing, everything, even the rocks, is in an incandescent and molten state. Here, then, in the depths below, is the great reservoir of heat for raising mountains, throwing up volcanos, ejecting springs of hot water, &c.

§ 99. Now it is interesting to know how these things, viz. the weight of the atmosphere, and the melted matter at the centre of the earth, were found out. It was found out that the earth grows warmer as we go down into it by the miners, for they discovered that the deeper the mine the warmer it grew at the bottom.

§ 100. Then with regard to the weight of the atmosphere. A pump maker went to Galileo, the famous philosopher, to know why his pump, which was a very good pump, would not suck the water up from the bottom of a well more than 32 feet deep. Galileo thought it was because the weight of the air was not heavy enough to balance a column of water more than 32 feet high; and he therefore suggested that the atmosphere must have weight. If the atmosphere have weight, said two French philosophers, then, as, when we ascend a mountain, we are nearer the top of the atmosphere than we are when we are in the valley below, the weight or pressure on the mountain top will be less than the weight or pressure in the valley. Let us try it, said they. Now it was inconvenient to get such an unwieldy thing as an old wooden pump to see how high the pump would suck water up in the valley, and then carry the pump to the mountain top to see how high it would suck up the water there; they, therefore, resolved to make their experiment with mercury, as being more convenient; for, mercury being about 13½ times as heavy as water, a column of mercury 29 or 30 inches high would balance a column of water 32 feet high. So they got a long glass tube, having one end closed; this they filled with mercury, and when filled, one of them placed his finger on the open end, turned it down, and set it in a basin or cup of mercury, still keeping his finger there until it touched the bottom; he then gently removed his finger, and the mercury fell in the tube until it was balanced by the pressure of the air on the outside. The space between the top of the mercurial column was the most perfect vacuum that man can make; it is called a Torricellian vacuum. The height of the column of mercury in the tube was accurately measured and marked. This was the first barometer. It has been greatly improved since, but its principle is the same. Subsequent observations with it show that the weight or pressure of the atmosphere upon any one place is always varying, sometimes more, and sometimes less, but seldom more than to the extent of three inches, or one pound and a half to the square inch. The original barometer was then, tube, mercury, and basin, carried to the top of Puy de Dôme, a lofty mountain in France, where the operation of filling, inverting, and measuring was repeated; and sure enough the mercury stood 3·3 in. lower on the mountain top than it did in the valley below. Thus it was *proved* that the air had weight.

§ 101. The rule is:—As you carry the barometer up, it falls one-tenth (0·1) of an inch for every 87 feet you carry it up; though this rule holds good only for the first few hundred feet. But really, the higher you go the higher you have to go to get the mercury in the barometer to fall the one-tenth part of an inch. This ratio is determined by a mathematical law; and there is now an ingenious mechanic in England * who has constructed a barometer of such exquisite nicety, that it will tell, within a few feet, the height of the loftiest mountains. All you have to do is, to leave your travelling companion at the foot of the mountain with one of these instruments while you go to the top to observe with another. The difference between the readings of the two shows the height of the mountain. This exquisite instrument may be worn in the pocket; it is not larger than a watch, and it is so delicate that it will show a difference between the pressure of the atmosphere on the floor and on the table. It is a great boon to geographers, meteorologists, surveyors, explorers, and to every attentive observer of nature.

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* E. T. Loseby of Leicester.

§ 102. With this much of previous explanation, and a review of §§ 55 and 56, and of 61 to 80, we are prepared to begin to consider certain modifications in the prevailing direction of the wind in different parts of the world, as shown in Plate 1. These modifications are according to seasons as well as place; upon many of them depend the well-being not only of whole tribes of plants and animals, but of nations also.

§ 103. Let us first study Plate 1 a little further. The calm belts, as they are found at sea, are always in motion; they are not stationary as they are here represented. Neither are they as sharply defined at sea; nor are they always between the same parallels as they are on the Plate represented to be. These bands and belts of winds and calms have their limits, it is true; but they are as variable and as vaguely defined as are the limits of the land and sea breezes on a small scale, or the monsoons on a grand one. Moreover, these calm belts, instead of always being several degrees broad, are sometimes only a few miles in breadth; and they, with the whole system of winds, travel 10° or 15° of latitude up and down the ocean, following the sun in declination—every year. So that, in August or September, they reach their extreme northern range, and their extreme southern in March or April.

§ 104. As the equatorial cloud ring which overhangs and accompanies the calm belt in its annual vibrations, reaches this or that place, such place has its rainy season. Thus the rainy season at Panama in 12° N. is in summer and autumn, but at Guayaquil in 3° S., it is in *our* late winter and early spring. Bogota, which is about midway in latitude between the two places, has two rainy seasons every year; one as the equatorial calm belt, with its cloud ring, passes over it going north; and the other, as it passes over it again returning south.

§ 105. This equatorial cloud ring encircles the earth, being disjointed over the Indian Ocean during the SW. monsoon, and sometimes, perhaps, broken for several days together, over the interior of Africa. It is formed by the vapour which the NE. and SE. Trade winds, as they blow over the sea, are continually pouring into the equatorial calm belt. Here, ceasing to go forward, and being forced to ascend (§ 67), this vapour, together with the air that has borne it along, and that now bears it aloft, expands; as the two ascend, they expand (§ 98) and grow cool. In this process, the vapour being compelled to part with a portion of its latent heat, is condensed, first into clouds, and then into rain. Hence it rains every day, and almost continuously, under the equatorial cloud ring.

§ 106. Now let the student turn to a map of the world, and point out the countries where the Trade winds blow, and the parallels between which the calm belts are to be found in this or that season of the year; remembering that the equatorial cloud ring, like the calm belt, travels (§ 69) up and down the ocean with the sun in declination; and that it is always behind the sun in its journey to the north, and then again behind it in its journey back to the South. For instance, the south edge of this equatorial calm belt and cloud ring, in March or April, is in latitude 3° or 4° South; for, as I have said (§ 103), its exact limits are always varying more or less, and its edges are as vaguely defined as are the places where the sea breeze begins and ends; and in August and September its northern edge is as high as the parallel of 15° or 20° North. The belt itself varies in breadth from a few miles to a few degrees; but the whole system of calm belts and Trade wind bands, preserves their relative position and travels up and down the ocean with this equatorial calm belt and cloud ring; i. e. they slide up and down the earth, going North in spring and summer, returning South in autumn and winter.

§ 107. Now, bearing this oscillatory motion in mind, and always remembering that these three calm belts, the two bands of Trade winds, and the two regions of Westerly winds, or counter Trades (§§ 61 and 62), preserve their relative positions with regard to each other, as so many black, blue, green, and yellow streaks would on a broad leather band, as you slip it up and down a revolving cylinder—remembering this, I say, it will not be difficult to point out on the map pretty nearly the position of each belt and band in May, June, and July, as they swing to the North; and again, in November, December, and January, as they swing back to the South. In the northern swing, the calm belt of Cancer reaches up as high as 35° or 37° North, each of the Trade wind bands, as they are found at sea, being 25° or 30° of latitude in breadth.

§ 108. These vibrations may seem a little difficult rightly to comprehend; but a little practice, after reading over the last two paragraphs carefully, before each attempt to trace this slipping up and down, will make it appear very simple. Thus I remember (§ 104), that the rainy season at Guayaquil, about 3° South, is at its height in March and April; for that is the time when the Republic of Ecuador is overhung by this cloud ring. I also remember that in June and July they have one rainy season at Bogota in 4° N, as this cloud ring and calm belt are travelling up into our hemisphere. That at Guatemala in 15° N., they have the rainy season in August and September; and they have it again in Bogota in January, as this calm belt returns to the South.

§ 109. I am aware that I am now entering the domains of Meteorology, but a knowledge of these facts is as necessary in the study of Physical Geography as of Meteorology. Indeed, it is as difficult to draw sharp lines between these two sciences, as it is between our Trade winds and calm belts. Nevertheless, by understanding the annual vibration of these belts, as the sun drags them up and down the earth's surface after him in declination, we have the key to the dry and rainy seasons of most places, and to much physico-geographical lore.

§ 110. Where the tropical calm belts are, there we have the dry season, as in Chili, in March, when the calm belt of Capricorn is at the extreme South end of its arc of vibration; and again in California, when the calm belt of Cancer is at the extreme North end of its swing. As these belts swing towards the Equator, the Westerly winds set in at the places which they have left; so we have the rainy season in Chili during our summer, i. e. *their* winter.

§ 111. In like manner, when the belts and bands return to the South, the Westerly winds of the extra tropical regions of the Northern hemisphere set in at places which the calm belt of Cancer has passed over, in its journey after the sun towards the South. Here *our* winter months are the rainy season, as in California, the countries bordering the Mediterranean, &c.

§ 112. Now we are prepared to announce a law of great importance in the study of climate, and of the physical sequences of climates:—In all countries where the seasons are divided into wet and dry, *it is the rainy season when they have the sea to windward of them, and the dry when they have the sea to leeward of them.* At those seasons, when the prevailing direction of the wind is *from* the LAND, the latter condition is fulfilled; and the former when the prevailing direction of the wind is *from* the SEA, as with Bombay during the SW. monsoon, and as with the west coast of Ireland, Great Britain, and the Atlantic coast of Europe, all the year round.

§ 113. Now, after these dry details, we are prepared for something more interesting, for we are ready to discover, even if we had not been told before, why the flora and consequently the fauna of Australia, and of the valley of the Amazon, should be so very different, the one from the other. Parts of the two regions are between the same parallels of latitude—they are both in the Trade wind regions of the southern hemisphere. In the valley of the Amazon, we have the broad-leafed plants; in Australia, the narrow. *Leaves* are the *lungs* of plants. Remember that.

§ 114. But why should that make the Amazonian leaves broader? Behold the number of watercourses that are in this part of South America; the country to which they give drainage is therefore, we may infer, well watered with showers. The Amazon alone, I reckon, discharges into the ocean perhaps ten times as much water as any other river in the world. On the contrary, look at Australia, with its little Darling—the only river of any consequence there. That tells you that water is scarce—that Australia is therefore a dry country. In the Amazonian climate, the roots suck up moisture from the soil; the leaves drink it in from the air; these spread themselves, and unfolding their broad expanse full in the face of the king of day, invite his rays and the winds to come, and by their processes, carry off the moisture and the refuse, for which the plant has no further need.

§ 115. In Australia, on the other hand, the air is dry, the sun hot, and the soil scantily supplied with moisture. There the vegetation can neither court the sunbeam, nor woo the winds. Its roots are in a thirsty soil, and its leaves are narrow; they lack moisture, and to escape the blaze of the sun, the narrow little things turn their sharp edges up to his fiercest rays, in order to escape as many of them as possible, and so screen themselves from the evaporating force of the wind also.

§ 116. Now then, it requires no great force of the imagination to depict an Amazonian forest with its jungles, its creepers and climbers, its air plants and their parasites, all in full vigour the livelong year; indeed the display there of force and energy by the vegetable kingdom is terrific. There the roadways are choked up, and old ruins literally torn down (not by the weather as with us), but by the vegetation, which sends its roots and fibres into every crevice and cranny, overrunning and tearing them down. One, therefore, may well conceive that the insects, the reptiles, the birds and the beasts that live upon the narrow-leaved plants of Australia, or prey upon each other, are quite different from those that are found among the broad-leaved plants, with their juicy fibre and abundant fruitage, of the Amazon. Fully to appreciate these differences, one has but to visit the Zoological Gardens in London, or the grounds of the Society of Acclimatation in Paris, and ask to see the fauna and the flora of the two countries. As for the latter, almost every private greenhouse or conservatory in the realm contains specimens sufficient to indicate the difference.

§ 117. Now you will be surprised to learn that this remarkable contrast between the flora and the fauna of these two regions depends simply upon the *way the winds blow*, and *how the land lies.* Turn to your globe or map, and you will see.

§ 118. Look at South America; you observe that it is in the shape, nearly, of a right-angled triangle; its base rests upon the Pacific to the west; and on the east its two legs, forming the right angle at Cape St. Roque, lie in such a direction, that the SE. Trades in one hemisphere, blow perpendicularly upon one leg, while the NE. Trade winds on our side of the Equator blow perpendicularly upon the other. These two winds, coming from the sea, and being loaded with moisture, strike the land to the leeward of them (§ 112). They drop their moisture down as they pass into the interior, which, falling in copious showers, makes the whole country to teem with both vegetable and animal life.

§ 119. Now turn to Australia and see how the land lies there: look at its eastern coast, and observe that instead of lying as the coast of Brazil does—namely perpendicularly to the SE. Trade winds—it lies nearly in the direction in which they blow. These Australian winds, therefore, instead of bearing inland their loads of moisture, which they have pumped up from the sea, blow parallel along the coast, fringing only the shore line with occasional showers.

§ 120. Let us refer again to Plate I., and back to the explanation of it, Book III.—to refresh the memory as to the general circulation of the atmosphere, and the prevailing direction of the wind in any latitude;—we now remark that all places in either hemisphere that are more than 35° or 40° from the Equator, are in the region of westerly winds; and that all places in either hemisphere, that are not more than 30° or 35° from the Equator, are in the region of eastwardly winds i. e. in the Trade-wind region.

§ 121. With the memory thus refreshed, turn again to your globe or map, and you will observe that the British Islands, the western shores of Europe, the eastern shores of Asia, the Japanese Islands, and both shores of America to the north of the parallel of 35° or 40° in the Northern hemisphere;—and that both shores of South America and New Zealand, are all in the regions of westerly winds, or counter-Trades.

§ 122. Now let us contrast the climates of these countries according to the general rule already given (§ 112). And first, of the British Islands and the western shores of Europe.—Here the prevailing winds are from the westward, with the sea to windward. The result is a winter climate so modified by the latent heat of vapour which these winds bring with them, and which is condensed over these countries, that all difference of temperature on account of difference of latitude, is completely masked; so completely that in the dead of winter, you may travel from Land's End to John O'Groat's House, and thence up to the extreme northern limit of the Shetland Isles,—a journey comprising a difference of more than ten degrees of latitude,—without coming to a single place with a mean winter temperature below 39°. Indeed, Mr. Buchan has shown in a paper read before the Scottish Meteorological Society,* that in January one may travel from Petersfield, in Hampshire county, all the way to the Shetlands, on the mean isotherm of 39° for that month. That is, the mean temperature for the month, of every place visited along the route, shall, when reduced to the sea-level, be neither above nor below 39°.

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* See No. 1. New Series of their Journal.

§ 123. Part of this evenness of temperature is due to the Gulf-stream; but when we remember that the quantity of heat set free from every inch of rain-fall on the island of Great Britain exceeds (§ 92) the amount created by the combustion of all the coal that is consumed in the island during several years;—and further, that this quantity is set free in the air over head once for every ten days on the average, we need not be surprised at the importance assigned in the physical economy, to the latent heat of vapour.

§ 124. Ireland, you will observe, is to windward of portions both of England and Scotland. The westerly winds, as they come from the sea, arrive first in Ireland, where they deposit a portion of their moisture; consequently, Ireland has a greater rain-fall than obtains on the opposite shores of England and Scotland. There should, therefore, be a more copious discharge of latent heat over head in Ireland; and the winter climate there should consequently be more mild than it is on the opposite shores. Observations show it to be several degrees warmer.

§ 125. I have said that the latent heat of vapour is much more potential in mitigating the winter climate of the British islands, than the warm waters of the Gulf-stream, and for this reason:—The warm water imparts its heat to the air by conduction (§ 86); that air, borne along in the channels of circulation, brings this heat to these shores by convection, and imparts portions of it again to the land by conduction. Now the capacity of air for heat is so very limited, that no less than 3,080 cubic feet of air would have to lose 1° degree of heat in order to raise a single cubic foot of water 1°; and in order that these westerly winds may convert this cubic foot of water into vapour, having only the same temperature as the water, they must borrow from sea and air, and render latent in the vapour, heat enough to cool 967 cubic feet of water 1°. The waters of the Gulf-stream being warm, supply this heat for evaporation more readily than they could, being cold. It is in this way, rather than by warming the air directly, that the Gulf-stream exercises the greatest influence upon European climates. The vapour in which all this heat comes to us is no warmer than the air, which wafts it to these shores.

§ 126. Now then let us compute, and see how many cubic feet of air will have their temperature raised 1°, when the vapour from this cubic foot of water is brought to the land from the sea, condensed, and its heat liberated over head. Multiply 3,080 by 967, and you will have it. But if you imagine this vapour to be condensed into hail or snow, then you would have by that process (§ 95) a further liberation of latent heat, and in quantities sufficient to raise 1°, the temperature of an additional 143 cubic feet of water. So that for every cubic foot of water that is evaporated from the Gulf-stream, and condensed, in the winter time, into hail or snow on the hills of Scotland, heat enough is set free to raise 3,418,800 cubic feet of air, 1° in temperature.

§ 127. You now begin to perceive what powerful influences the winds, and the vapour which they bring, exercise upon climates. But, in the regulation of climates, vapour has other and important offices to perform which have barely been alluded to, but to which attention will be called at another time; for, but for these offices, these green and happy islands would scarcely *be inhabitable.*

§ 128. Again, take the climate of Norway;—there you may go along the western coast, from the Naze, in lat. 58°, to North Cape, in lat. 71° (=13° of lat.), without altering the mean winter temperature, as much, as in a winter's day, you often change your actual temperature in passing from one apartment to another under the same roof. So little, where there are copious winter rains, has mere difference of latitude to do with climate.

§ 129. Indeed, a traveller on the western coast of Norway, who should wish to change his climate as rapidly as possible, would do so, not by going towards the North Pole, but by travelling due east, and so hastening by the shortest route, beyond the limits of copious precipitation; for it is obvious that the farther the winds penetrate into the interior of continents, the drier they become, inasmuch as they drop down rains to water the country and feed the rivers as they go. The same remarks apply to the winter climate of Columbia and Oregon in North-western America;—to New Zealand, to Southern Chili, and Patagonia, and so down to Cape Horn in the South American winter. There the Patagonian Andes rise up so abruptly from the sea and are so high, that the precipitation there is often heavy enough to cover the surface of the sea for several miles out, with pools of fresh water.

§ 130. Now contrast the above-named lee shores of the northern continents with their windward shores between the same parallels of latitude.—We have been studying the climates along the western shores of Europe, from Land's End, in lat. 50°, viâ the coast of Norway, to North Cape, in lat. 71°, and we have seen that nowhere along the sea front of these shores, is the winter climate severe enough to close a single harbour with ice.

Now turn to the country on the east coast of America between the same parallels,—you observe it extends from Labrador up to the Arctic Ocean. Here in England, your flocks lie down in green pastures all the year round; but in Labrador, the winter is so severe, that even man himself can scarce find subsistence; and as you proceed north, instead of being able to find a route along which you may preserve, at the sea-level, a mean winter temperature of 39° (§ 122), through ten degrees of latitude, you come to a country so cold as to be positively uninhabitable. The soil produces no green thing; and before you reach the lat. of North Cape on this windward shore, the harbours are fast bound, winter and summer, in fetters of ice.

§ 131. In this cold country, as in these gentle climates, the prevailing winds are from the westward. But, instead of coming from the sea in America and blowing upon Labrador charged with heat-laden vapour, they come from the land, and are for the most part dry. Now Professor Tyndall has shown by a most beautiful series of experiments, that dry air—chemically *dry* air—has not the power of obstructing, in the least, the heating rays of the sun as they pass through the atmosphere to us. They pass through pure dry air, he maintains, as freely as they do through the ethereal medium above and beyond it; and it permits the earth to radiate (§ 86), that is, to pour the heat that it has received from the sun, back again into the stellar spaces precisely as though there were no atmosphere; so that, were our planet surrounded by a chemically pure and dry atmosphere, the beams of the sun could pass to and fro through it, by the process of radiation, and without the loss or the absorption of a single ray. Were the earth enveloped in such an atmosphere, we should find in all countries, the heat of the sun insufferable by day, and the cold of the earth unbearable by night.

§ 132. Happily, though, for this beautiful world, the atmosphere is *not* pure in the *chemical* sense; and the vapour which is always present in it, in quantities larger or smaller, has the power, whenever these rays attempt to reach the crust of the earth, or to escape from it, of entangling them, of striking them down right and left,* and of absorbing them in proportion to the quantity of vapour that happens to be present.

§ 133. We now approach the effects of some of those other unenumerated influences of vapour, to which further allusion (§ 127) was promised. The abundance of aqueous vapour in the air of Great Britain, protects these islands from the fierceness of the sun's rays in Midsummer; and the particles that remain after one of those warming showers in winter, stand like sentinels in the air, striking down ray after ray of that liberated heat, which the lower air and the earth have received from the shower, and which they are trying, by the processes of radiation, to get rid of and to send off into space again.

§ 134. Behold, now, the benign offices and influences of this invisible vapour in the terrestrial machinery.—It not only conveys heat and moisture from climes and places where they are not wanted, but it dispenses them where they are required; and then, spreading itself out as a mantle in the sky, it serves the green earth as a blanket in winter, a screen in summer.†

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* Heat as a Mode of Motion, by John Tyndall, F.R.S., &c.

† Among other exquisitely beautiful results obtained by Professor Tyndall during his experiments upon radiation, is the discovery that perfumes of our sweetest flowers have an appreciable effect in preventing the escape of heat by that process—some.

§ 135. Notwithstanding the air of Labrador, for the most part, comes from the land, it has some vapour mixed with it; but not enough to impress upon the earth, during winter precipitation, any considerable amount of heat, or to impart it to the air in quantities sufficient to give softness to the climate there; nevertheless, it does impart enough, now and then, to give temporary softness to the winter weather; for in most parts of America you may, towards the end of what they call 'a cold snap,' hear the people saying, 'Ah, it's clouding up; it's going to turn warm. We shall have snow.' And so they do. This warmth is the latent heat of vapour

perfumes more, some less; but all very much more than the atmosphere itself. This discovery is a little philosophical gem of the first water. In it, we have the very essence of poetry: it suggests sweet companionship in the garden at the silent hours of the night; and tells of a mute sympathy among the flowers of the field, akin to the purest affections of the human heart.—As the dews of evening begin to fall, we are reminded that the earth has commenced to grow cool; we know then that the forces of radiation *from* the earth, are getting the upper hand, over the powers of the sun upon it. Then the violet commences to shed its fragrance most lavishly;—spreading its sweets out like a little garment, and seeking to screen itself under the protecting folds of its own delicious perfume, from the chilly night. The lily of the valley, the rose, and the neighbouring flowers, lend their tiny mantles of delicious odours to stop the escape of heat; and so increase their warmth. And lastly, the yellow jessamine,—the sweetest of all flowers,—and the lordly magnolia, add their superb coverlets of perfume, spreading them out far and wide from the tree-tops—thus piling up the invisible covering and helping to keep warm their modest little neighbours below.

Every department of physical science teaches us that the whole world is kin; as for man and all living creatures, they are but so many pieces of mechanism wound up and kept agoing by the vegetation of the earth, which in turn, derives all its forces, *its powers*, and its wealth from the light and heat of the sun.

made sensible by the conversion of that vapour into snow. Thus, even in midwinter, they occasionally feel the heat that has been brought to them from the lakes, the rivers, and the forests of the interior by this genial little carrier. But then, after a snow storm, there is not enough vapour left in the air to prevent the earth from quickly radiating the warmth thus received; and so the weather soon turns cold again.

§ 136. It is, therefore, chiefly owing to the small amount of vapour in this American air, that the sun succeeds in impressing his rays upon the earth there more freely in summer, and the earth itself is enabled to send off its heat by radiation more rapidly in winter;—and that the climates in America, are so much hotter in summer, and colder in winter, than they are in corresponding latitudes in England. Hence you perceive the difference between a continental and a marine climate—the latter is damp and uniform, neither hot in summer, nor cold in winter—such is the climate of England, Norway, &c. The former is dry and extreme; very hot in summer, very cold in winter. Such are the climates of Labrador, Siberia, &c.

§ 137. The climates of Eastern America and Asia are also continental. On the other hand, the climates of British Columbia and Oregon are marine; they are duplicates of those of Western Europe. There the sea is as it is here, namely, to windward; but its waters are not so warm. Yet by reason of higher mountains in North-western America, that country has a greater rain-fall; and when the vapour is condensed into rain or snow, the amount of latent heat discharged there makes up for the difference in the temperature of the two seas.

§ 138. To illustrate, in a still more striking manner, the influence upon Climates, exercised by the vapour in the air, not only by reason of the latent heat, which it contains, but also by reason of its power over radiation, allow me to refer to one or two more cases, as the province of Yakutsk, for example, in Asiatic Russia, and especially to that part of it which is situated between the parallels of 60° and 66° North. This is a grazing country; for the summers, by reason of the dryness of the atmosphere, are warm enough for the grass to grow. But in winter, the thermometer sometimes sinks down to 104° *below the freezing point.* Now this is as great a degree of cold as any Arctic explorer ever encountered. The city of Yakutsk,—where this extreme temperature was observed by Erman,—is in the latitude of only 61° 40′; to the North, South, East, and West, it is far removed from the sea.

§ 139. The cool nights, the scorching sun, the severe winters, and hot summers of the great steppes of Central Asia, were formerly a great puzzle to travellers who ventured there. But now, these new revelations of science, concerning the power of vapour over the radiation of heat, seem to make it all plain. The air of the steppes lacks vapour enough to intercept the heat of the sun by day, and to prevent its radiation from the valleys by night. Also travellers, in crossing the great desert of Sahara, in Africa, which is under the calm belt of Cancer (*vide* Plate 1), and partly intertropical, have reported that by day the sand there is as fire and the wind like flame; yet in this land of fire and flame by day, they find it cold enough at night to freeze the water in their canteens.

§ 140. Enough has been said to remind the reader that, in studying the Physical Geography of this or that country, he should not pretend to judge of its climate, much less of its flora or its fauna, which was formerly too much the custom of geographers to do, by latitude alone, or even by the scarcely less imperfect method of isothermal lines,* but both by latitude and isothermal lines in connection with the prevailing direction of the winds, and the quantity of vapour they bring.

§ 141. Let us make ourselves clear as we go; and that we may do this, let us, in addition to all the cases which have already been given, take for illustration, the Island of Madagascar, on the east coast of Africa. That island is situated between the parallels of 12° and 26° S. Latitude. It is in the SE. Trade wind region; and as in Brazil, these winds, as they come from the sea, impinge perpendicularly upon its shore line. It is traversed from North to South by a range of mountains; consequently, precipitation is copious, and its vegetation is quite Amazonian. The Mozambique Channel, which separates it from Africa, is not broad enough fully to replenish with vapour these partially dessicated winds; they consequently reach the continent as, comparatively, dry winds. The consequence is, the difference between the flora and fauna of Madagascar, and the fauna and flora on the neighbouring shores of Africa, between the same parallels, but merely on the opposite side of a channel, is quite marked. In like manner, Ireland depletes the winds of vapour which they would otherwise bear across St. George's Channel; and the island of Great Britain still further depletes them of that which otherwise they would bear across the North Sea and dispense along the shores of the continent. The rain-fall at West Port, on the west coast of Ireland, is double the rain-fall at Tullough, between the same parallels of latitude on the east coast. Moreover, the winters of Ireland are several degrees warmer than the winters are in the same latitude, but on the opposite side of St. George's Channel.

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* *Isothermal lines* are lines of equal mean temperature for a month or a year.

§ 142. Deserts, as well as mountains and islands, have also their offices to perform, under the ordinances which regulate the terrestrial economy which we have been studying. But enough has already been said with regard to the beauties and arrangements of the physical machinery, to satisfy the student that there is design in the winds, order in the sea, plan in the direction of a coast line, harmony between land, air, and water, and good in it all. We now turn to other parts of this exquisite physical machinery, and proceed to examine some of the wheels within wheels, the operations of which we have been admiring so much.

BOOK V.

§ 143. We now understand what is the prevailing direction of the wind *at sea*, on any parallel of latitude that may be named. We also understand what are the main features of the climates in most parts of the world; and that at sea the climates, because they are marine (§ 136), are more equable than they are on the land. Indeed, both as to winds and climates, we have at sea, the rule;—on land the exception; were the earth entirely covered by water, the circulation of the atmosphere would be very much as it is represented by the arrows and calm belts on Plate I. to be.

§ 144. But when we come to the land, we find that every mountain, every hill, plain and desert,—especially the mountains and deserts,—exercise an influence and control, more or less important, over the direction and force of the wind; this influence extends in some cases for more than a thousand miles out to sea. Even England, as small a space as it occupies in the great aërial ocean, and as far removed as it is from those parched regions upon which the heat of the sun beats down in summer with all the force of the vertical ray, has its office to perform in regulating the movements of this grand machine, e. g.:—

§ 145. Many gales of wind, coming from the west and striking the British shores, pass over the land, and continue their course to the eastward, blowing with fearful violence at sea both to the east and west of the island;—but moderating their fury to a wonderful extent as they pass over the land. Lord Wrottesley's wind gauge, kept nearly mid-way the island in the county of Stafford, shows, by the average of a great number of observations, that the strength of these westerly gales is felt with exactly twice the force in Liverpool, that they are at his observatory near Wolverhampton.

§ 164. The reason is this:—The force of the gale is broken by the hills, and the wind is so entangled among the trees and obstructed by the hedges and the houses, that it can only make half speed in crossing the island. Now, if we imagine one half the air which the gale puts in motion to be thus obstructed in crossing the island, the other half must move at redoubled speed; and this it does by mounting up far above hill and tree top, and clearing the island with all of its obstructions at a bound, as it were. Thus this island becomes a part of the machinery we are studying, for by causing the gale to mount up and over-leap the island, it promotes vertical circulation.

§ 147. Vertical circulation is the process by which the air from the pure blue vaults of the sky is brought down for our use; while the mephitic vapours from the swamps and dank places of the land are taken up from the surface, and carried off to the proper laboratories far away among the workshops of nature for purification. Vertical circulation, which is not so obvious as the horizontal circulation which is carried on by the winds, is not less important in the physical economy.—It keeps the air in wholesome adjustment, and in a state of proper admixture. But seeing that there are no mountains and trees to obstruct the air at sea, and make it leap up in the gale, how, it may be asked, does the atmosphere derive the force there, for its ascending *and descending* in columns?

§ 148. Ans. :—To give it this force is one of the offices (§ 127) reserved for the vapour of water. The invisible particles of this busy and wonderful little agent perform at sea, the work we have just ascribed to the hills, houses, hedges and trees on the land, and in this way :—Vapour you know (§ 76) is lighter than air; and as it rises from the sea, its little vesicles become entangled among the particles of air, and so carry them up. Air from above, then comes down to take the place of that which has been carried up. Arrived in the upper regions, this vapour is often condensed into clouds. The heat thereby liberated is expended in warming, expanding and sending up the air still higher. These clouds then, though they give no rain, have their offices to perform either in screening (§ 89) the earth from the sun's rays, or in preventing the earth from getting rid of its heat too lavishly by radiation. The sky is seldom seen in the Trade wind regions at sea, without some such clouds in it. If, even in this country, you will watch on a summer's day, when you see the sky mottled with clouds, you will see them changing their form, disappearing and melting away in the blue vault. They are then converted into vapour again; in this processs, they rob the air in which they float, of its heat, and so make that air cooler; it then contracts, grows heavy, and descends.

§ 149. Thus we are reminded that in the physical economy nothing is wasted, everything is of use; and that no expression on the face of nature is without its significance. Here we have led you to the discovery, that even the cloud without rain has its offices to perform in making this world so beautiful. To keep the air pure and the earth green, there is a perpetual hoisting up, and letting down, of invisible buckets by ropes and pulleys that are fastened in the 'lither sky,' and worked by hands equally invisible.

§ 150. Were the atmospherical machinery simply such as it is on Plate I. represented to be, this branch of physical geography would be easily mastered. But instead of the aërial machinery doing its work by the help only of such simple appliances and direct movements, it has wheel within wheel, and movement within movement,—all complicating it in a wonderful degree. As an illustration,—the winds are not always from the westward in England; they blow now and then from all quarters, sometimes from the NE. or SE., and indeed from every point of the compass. They blow upwards also, and they blow downwards. Then as to the rains, they are more abundant at some seasons than at others. In like manner, and in some countries, the winds blow for one half of the year in one direction, and for the other half in quite the opposite direction perhaps. Of course this produces its corresponding effects upon climate.

§ 151. In speaking of the circulation of the atmosphere in Book III., we there considered only the winds, which are its horizontal movements at and near the surface of the earth; but we must remember, that as we have just stated, these are not the only movements of the grand machine; it has vertical circulation as well as horizontal, as you may remark whenever you see a cloud of dust rising up, or by observing the motion of the snow flakes in a calm. Moreover, it is obvious, that in such places as in the Trade-wind regions, where the surface wind is always blowing towards the Equator, there must be counter-currents over head, by which the supply of air to make Trade-winds of, is kept up. *Reason* teaches this, and observation confirms it. In

January 1835, the sun was darkened for two days in Jamaica by a shower of ashes from the volcano of Coseguina, 800 miles to *leeward* in Central America. Ashes also fell at the same time on the decks of the ship Conway, 700 miles to the SW. of the volcano, in the Pacific. These three points, Jamaica, the volcano, and the ship, were all nearly in a straight line NE. and SW.; they were in the region of the north-east Trade winds. These winds bore the ashes SW. to the ship; but portions of them, rising above the surface wind from the NE., were taken by the upper current, and borne back to the island of Jamaica in such showers as to obscure the sun for two days. We proceed now to consider some of these modifications in the general system of atmospherical circulation already pointed out, and the causes of them.

§ 152. The most striking of these modifications are the monsoons, of which the deserts and arid districts of the interior are the chief cause. The feathered arrows on Plate 2 represent monsoons. This plate shows where the monsoons blow *at sea*, for they blow on land as well; and the student, after attentively considering this plate, should be required to point out on the globe, or a map of the world, the various coasts and seas where monsoons are known.

§ 153. Monsoons are, as a rule, either the NE. or SE. Trade winds turned away from their Trade-wind quarter. This turning away is generally caused by the rarefaction of the air over some arid plain or heated district that can make itself felt afar off, so as to create a rush of air from the sea to restore the equilibrium on the land.

§ 154. These winds blow generally in the summer of their hemisphere, when the rays of the sun have most *power over* the plains to be heated up. Consequently, it is the NE. Trade winds that, in our hemisphere, are turned out of their course, and made to 'blow monsoons' for us in summer and autumn, while the SE. Trade winds 'blow monsoons' in the Southern hemisphere during our winter and spring, which is *their* summer and autumn. Thus in India, the SW. monsoons, which are the NE. Trade winds turned *back*, blow from May to October. In the Gulf of Mexico, the SE. monsoons there, which are the NE. Trade winds turned *aside*, are at their height in August and September.

§ 155. It will be remarked that there are no monsoons of moment that originate in the Southern hemisphere, except the monsoons along the coasts of Australia. The reason of this is, that there is in comparison, so much less land in the Southern than in the Northern hemisphere for the sun to play upon; moreover, most of this Southern land, as South America and South Africa, is better watered than the far inland plains of the North, and is therefore more thickly covered with vegetation, and better protected from the sun. We may infer from the feeble character of the Australian monsoons, that there are no very extensive deserts, as compared with Sahara, in the interior of that semi-continent; hence the Southern hemisphere is poor in monsoons.

§ 156. To explain the monsoons, we have to refer back to § 90, and refresh our memories with what is there said about 'land and sea breezes;' for these are a sort of ephemeral monsoon in miniature. The land and sea breezes alternate with day and night, and are due (§ 90) to the heating influence of the sun upon the land by day, and the cooling effects of radiation from it by night. The monsoons, on the other hand, *are annual*; instead of alternating once a day, they alternate once a year, and are caused by the heating influences of the sun upon the land during the summer, and its cooling down again during the winter. All who live near the sea-shore in intertropical countries, or who visit it on a hot summer's day, are familiar with the sea breeze. The land breeze is more gentle; generally it comes at night.

§ 157. The monsoons of the Indian Ocean are the most famous of any; they are on the grandest scale; they first attracted the attention of navigators; they divide the year there into its seasons of wet and dry; they are the best developed, and to them we now beg to turn our attention.

§ 158. In the summer time, partly from the great dryness and purity (§ 39) of the air, and partly owing to the nakedness of the land, the great deserts of Cobi and Tartary, as well as the Steppes of Asia, become very much heated. They warm the superincumbent air, causing it to expand and ascend, precisely in the same way as in the case of the land and sea breezes, already explained. But instead of these immense plains being able to adjust their heat accounts, so to speak, every evening with the sea, as in the case of the sea breezes, the heat that they receive during a summer's day cannot be got rid of during the night; the sea is too far off to send in its refreshing breezes to help cool these burning sands; so the heat on the land continues to accumulate, as the rays of the sun grow more and more powerful; the air, over an area of many thousand square miles, is made to go up in ascending columns day and night. It is winter before the equilibrium is restored; and then, 'the wind returns to his circuits.'

§ 159. To supply the in-draught called for by this summer heating, there is a demand made upon the winds far and near, and they come rushing in with cooler air from the sea a thousand miles away and more. This sea-air is loaded with vapour, which, on condensation, is made, by the liberation of its latent heat, to 'add fuel to the flames,' and to spread still wider the monsoon influences.

§ 160. On their passage to those heated plains, these vapour-laden winds have, as you will see by looking at a map of Asia, to cross certain mountain ranges. These rob the winds of their moisture, bringing down torrents of rain, liberating, consequently, immense volumes of heat, which serves to rarefy the air still more, and to cause the Indian monsoons to be felt at sea even beyond the Equator, and as far, sometimes, as the parallel of 15° South.

§ 161. As the sun returns to the South, and the winter approaches, the over-heated Steppes and plains begin to cool down; there is then not such a demand for the cooler and moist air from the sea; precipitation ceases; and then those causes which produced the SW. monsoons begin to decline, while those which produce the NE. Trade winds gain the ascendancy. These in India, because they blow for six months in the direction opposite to that whence the SW. monsoon come, are called the NE. monsoons. They really are the NE. Trade winds; and, as you will see by looking at the map, they come mostly from the land. They are therefore, for the most part,—at least, as far as India is concerned,—rainless winds. They make the dry season there.

§ 162. Now then, to fix this explanation in the memory, turn to a map of Asia, and examine its principal deserts and mountain ranges:—You will observe a great central region stretching away from the Caspian

Sea, 3,000 miles to the East. It varies in breadth from a few hundred to 1,500 miles, and is nearly bisected by the parallel of 40° N. latitude. Now, take your pencil, and by drawing a very irregular line on the map of Asia, separate the head waters of all those rivers, as the Obi, the Yenisee, the Lena, &c., that flow North into the Arctic Ocean, from those, as the Ural, that flows South into the Caspian Sea, and from others that lose themselves in the sands, or in the lakes of these central regions that have no outlet to the sea.

§ 163. Continue to draw this line with the pencil, so as to separate the head waters of the Amoor and its tributary, the Soongari, from those inland streams also that lose themselves in the lakes and sands of Mongolia, and so on to the South, separating, in like manner, the country that is drained into the ocean by the rivers of China and India, from that interior country—as most of Mongolia, Turkistan, Affghanistan, and Persia,—that has *no* ocean drainage. This line brings you back to the Caspian Sea, and incloses a great inland and thirsty region, by the influence of which upon the winds, the rivers of India, China, and Asiatic Russia, are supplied with water from the sea.

§ 164. Now, you will have observed, that the head waters of all those rivers that, from this pencil line, flow North, East, or South, into the great and wide sea, take their rise under some mountain or other. Mountains have the power, as has already (§§ 35-38) been shown, with regard to the Andes, of robbing the winds of their moisture. The mountains, which divide the waters which flow outward to be discharged into the great oceans, from the waters which flow inward and lose themselves in the lakes and sands of this great inland basin, rob the sea winds—the monsoons—of their moisture, as the Andes do the SE. Trade winds of theirs. These monsoons, then, like the South-American Trade winds in Peru, tumble down upon the Steppes and plains and basins within the pencil line, as dry and almost rainless winds.

§ 165. Being thus deprived of most of its vapour, the air over the inland regions included within the pencil line (§ 89) becomes too dry to protect these barren plains from the scorching rays of the sun, as in summer he pours them down with almost vertical intensity. Here, then, is the cradle of the great monsoons of India, and such the process by which these Steppes and deserts become so highly heated in summer, as to raïse columns of rarefied air in such huge volumes as to create a draught extending throughout the surrounding regions for thousands of miles. As the inrushing air from the sea reaches these mountains, its vapours are condensed; their heat is liberated, warming and expanding and sending up still other columns of highly rarefied air. Thus 'fuel is added to the flames,' and the inrush is quickened; and as it increases it extends farther and farther out to sea.

§ 166. Let us pause here a moment to contemplate the magnitude of the forces that are thus brought into play. On a clear summer's day, the sands and rocks in these inland regions are often hotter than the hand can bear. Now imagine a district of thousands of square miles so heated; and remember, that for every gallon of sand or cubic measure of rock thus heated, heat enough to warm and rewarm over and over again hundreds of such measures of dry air, has been lodged by the sun in those rocks and sand. If you can conceive of this, you may gather some faint idea as to the volumes of the ascending columns of air, which, heated by the sun by day, and by the rocks and sand by night, throughout these regions of Central Asia, makes its escape to the sky. From this you may form a vague idea of the demand thus created upon the cooler air of the surrounding regions to restore the equilibrium. To compare great things with small, it is the in-draught created by a city in flames, compared with the gentle draught caused in a remote corner of the room by the fire on the hearth.

§ 167. Then with regard to the heat set free in the clouds:—while they are pouring down the water to make these great rivers of Siberia, China, and India, the winds with water, in the shape of vapour, for all these rivers, are drawn from the sea, and in the condensation of this vapour, heat enough is evolved,—chiefly in the course of the six months from May to October, to boil away all the water that these rivers give back to the sea during the year.

§ 168. In the terrestrial machinery, the land acts as a condenser for the sea, and I dwell upon the quantity of heat that is taken up from the sea by vapour and distributed over the land, because it exercises such controlling influences upon the climates and productions of the earth. If the sea be the boiler whence is raised the vapour for all the water that the great rivers of Asia return into the sea, let us enquire for the furnace that supplies the heat for lifting these rivers up as vapour, for carrying them to the mountains as vapour, and letting it down as rain.

§ 169. According to Pouillet and Herschel, the quantity of heat impressed upon the earth daily, is enough to raise from the freezing to the boiling point 7,513 cubic miles of water. Imagine, a caldron as large as Wales, and one mile deep, filled brimfull with ice-cold water. If all the heat which the sun dispenses to the earth any day in the year, whether in the hottest day of summer or the coldest day in winter, could be concentrated upon this caldron, it would make the ice-cold water in it boiling hot. To fill such a caldron, all the water that is discharged into the sea by the rivers of India, in the course of several years, would not suffice.

§ 170. We now behold this great central plateau of Asia playing a most important part in the physical machinery of our planet. It draws the air from the Arctic Ocean, from the Chinese Seas, and the Indian Ocean, which brings with it, in the shape of vapour, water to feed all the great rivers of Asia. For this plateau only, these winds bring none; it is all dispensed by the way. For though you observe that within the region bounded by the pencil mark, there are rivers, as the Amoo and Sir Daria in Turkistan, which empty into the sea of Ural; the Ili in Russia, which empties into Lake Balkash; the Tarim in Mongolia, which empties into Lake Lob-Nor &c.; yet none of these rivers give sea drainage. They all empty their waters into an inland sea, or into lakes without an outlet, or are simply lost by evaporation. Therefore the quantity of water taken up from this great central region by evaporation, is just equal to the quantity let down again by precipitation. We infer that these quantities are equal, because the inland reservoirs into which these rivers discharge themselves never run over and never go dry. Hence the remark just made, that the winds from the sea bring no rains for the rivers of this grand inland basin.

§ 171. Now since this remarkable region is, for the most part, surrounded by mountains that are everlastingly capped with snow, the question may be asked, why, in the process of ages, do not the tops of the mountains, as the Himalaya for instance, become piled up with snow as high as the sky? This question might be urged still further with the remark, that with those annual changes which draw the vapour-laden winds, as the SW. monsoons, from the sea, the fall of snow is heavy; much of it is in the region of perpetual ice, where no thaw ever takes place; why then, does it not accumulate?

§ 172. The answer is, there are on these snow-clad mountain heights, as there are throughout the domains of nature, compensating influences at work; much of the snow, especially that portion of it which is near the snow line, is gradually melted or partially compressed into ice; accumulating, under this process, immense masses of ice and frozen snow are formed, which continue to increase, until by their own weight they commence to glide down the mountain in the shape of glaciers. Thus they act as reservoirs in the rainy season, to become feeders for the springs in the valleys below, during seasons of drought. But ice and snow may be evaporated, as well as water. In America, as well as on those mountains where the air is much drier than it is in England, the phenomenon of the waste of ice and snow, by evaporation, is familiar to everyone. In the coldest weather there, the laundress hangs her clothes out on the line to 'freeze dry.' When there is a fall of one or two inches of snow, and the thermometer remains below the freezing point for two or three days, even though there be no thawing in the sunshine, the snow will all disappear; so also, when the roads in Virginia become muddy and freeze, be the 'cold spell' never so severe;—yet, if it last for a few days, the roads become as dry and as dusty as they do in the greatest drought of midsummer. Agassiz found that the glaciers of the

Alps lose several feet annually by evaporation. To give an idea of the rain-fall in some parts of India, during the SW. monsoon, I refer again to Chirra-Poonjee (§ 40), on the acclivities of the Garrow mountains. In a single month there, rain has been known to fall to the depth of twelve feet three inches, when during the six months of the NE. monsoons, not a drop is known to fall throughout extensive districts.

§ 173. In like manner, the monsoons on the West coast of Africa are caused by the highly heated plains and deserts of that continent. The monsoons of the Gulf of Mexico (§ 154) are due to the plains of Texas, and the table lands of Mexico. These monsoons give Mexico and Texas their rainy season, while those of Costa Rica in the Pacific, are caused by the heat evolved in condensing vapour on the mountains for the rainy season of Central America.

§ 174. Observe also Arabia and the Red Sea; both are rainless. The Red Sea is in the region of the NE. Trade winds; it is also in the monsoon region. These Trade winds (§ 161) come to it over a dry country. They lack moisture; they have none to let down upon the land, and it is parched; on the other hand, they suck up moisture from the Red Sea; they bear it off into Africa, where the Mountains of the Moon rob them of it for the Nile. You observe that no rain falls upon the Red Sea; that it has no rivers running into it; and it is the only sea in the world without tributaries from the land. You observe also, that, with the Red Sea on one side, and the Indian Ocean on the other, the rectangular form is also given to the East coast of Africa, somewhat resembling that (§ 118) which causes Eastern South America to be so abundantly supplied with rains. Why Africa is not supplied with equal abundance is obvious at a glance. The SE. Trade winds, instead of blowing upon the East coast of Africa all the year, as they do upon the coast of Brazil, are converted into SW. monsoons, and are made to carry their moisture for six months in the year to India for the rainy season there.

§ 175. The farther we go in this beautiful study of Physical Geography, the more we begin to comprehend that sea, earth, sun, and air, are all parts of a mechanism for making the whole world kin. Everywhere throughout the domains of nature, and wherever man has been permitted to carry his investigations, we see the evidences of order and arrangement, and the adaptations of each part to each, and of the whole to the parts. We have seen (§ 118) how, if the direction in which a coast line trends, had been different; or, if the way the wind blows had not been just as it is; or (§ 170), if the deserts and table lands had not been placed where they are; or if the mountain ranges (§ 39) were to be shifted; or if the proportions between land and water had been different; or if the arrangement and disposition of seas, continents, and islands, over the face of the earth, had been according to some other plan;—in short, if any or all of these terrestrial arrangements had been different from what they are, the vegetable world would have felt the effects of such differences, changes, or alterations, and it would have been different too; and consequently, the insects, the birds, and the beasts, that subsist upon the vegetation, or prey upon those that do, would have been different in many respects from what they are; and precisely what they are, and as they are, they were, we may be assured, intended to be by that great, good, and wise Being that caters for the sparrow, and clothes the lily.

§ 176. In this connection, remember what we have learned in Books II., III. and IV:—how the Andes (§ 36) rob the winds from the Atlantic of their moisture, and make Peru on the West, a rainless country;—how, in the same way, but not to the same extent, because the mountains are not so high, Ireland is made to (§ 141) lessen the rain-fall upon Britain;—and how this island again lessens the rain-fall upon Holland, Denmark, and Norway; and so helps to regulate climates there, as Madagascar (§ 141) does in Africa. Observation teaches that every modification of climate, however produced, is followed by a corresponding change in the flora and the fauna in the country whereof the climate is altered. The records of geology show that the climates of Great Britain and the Continent, as well as many other parts of the world, were once very different from what they now are.

§ 177. With such evidences of design, as these in the terrestrial arrangements and in the physical economy of our planet, we might as well say that the springs and wheels and cogs of a watch were all made and put together by chance, as to say that the operations of nature are by chance. They are all in obedience to law and order, and in conformity with the expressed design of the Creator for making the earth an habitation fit for man. Who, after studying and expanding what has been said in this little work, can fail to read beauty and significance—new import and fresh pertinence—in the Prophet's question, when, with hallowed lips, he exclaimed: 'Who hath measured the waters in the hollow of his hand, meted out heaven with a span, and comprehended the dust of the earth in a measure, and weighed the mountains in scales, and the hills in the balance?' Physical Geography teaches that, if these metes, bounds, weights and measures had been out of their present proportions, all nature would have been out of her present adjustments.

§ 178. Take, as an illustration, the snowdrop that decks our garden walks, as it lifts its head from the border in late winter or early spring;—let us call in and examine this little mute, and see what testimony it can give concerning this view. You observe, it bows its head to flower; and if you will take the trouble to watch it a few weeks, perhaps days, you will see it after a while lifting its head, and standing erect. Now, if you will call in the botanist to tell what it means by this change of posture, he will tell you that, in order for it to obey the command to 'yield seed after its kind,' its vegetable structure is such as to require it, first to bow, that certain processes of fructification should commence, and then to stand erect, that they may be perfected; then, if you will appeal to the geometer, he will, impressed with the dignity of his science, remind you that 'God works by geometry,' and explain to you, that, had the forces of gravitation been less than they are, this little flower could not have bowed its head at the right time; that had they been greater, it could not have stood erect, as its vegetable well-being required, and consequently it could not have obeyed the voice of its Creator in yielding seed; and that, therefore, you may conclude that when it was created, the whole earth was measured from pole to pole, from centre to circumference, and weighed, so that the proper strength of fibre might be given to its tiny flower stalk, and the vital energy even in the little snowdrop adjusted to the mighty forces of gravitation.

BOOK VI.

§ 179. We have now contemplated and examined as parts of the machinery concerned in the Physical Geography of our planet, the rivers, the rains, the mountains and valleys and plains, the aqueous vapour that floats invisibly in the air, the deserts, the islands, and the clouds; we have pointed out offices and influences for them all; and we have had our minds enriched, and our thoughts ennobled, by the contemplation of what they suggest. There are other parts of the grand machine not less marvellous in their beauty and rich in the wonders of their performance. In these, none can surpass the great and wide sea. Let us then examine it as a part of the physical machinery that we have been studying so patiently together.

We have been told (§ 3), and may see by looking at a globe, that nearly three-fourths of the earth's surface is covered by the sea; and it has been computed, —but from very imperfect data,—that all the water in the sea weighs about as much as would 400 of our atmospheres. This is only a conjectural estimate, for we do not know the depth of the sea, except in a few places here and there. But judging from the deep-sea soundings that the author procured to be made when he was at the Observatory in Washington, he has computed the average depth, roughly, to be about two miles and a half.

§ 180. Why the sea was made so large is beyond our ken. But we must remember the mighty offices it has to perform, the magnitude of the designs it had and has to accomplish. Geologists tell us that time was, when most of what now appears dry land was covered by the sea; that the very tops of the Andes are piled up and strewed with the remains of marine animals; that 'Albion's chalky cliffs' are the work of the sea and its artificers. The sand in the soil of all countries is a monument of the labour performed by the waves of the sea in grinding the rocks and the pebbles on the shore into powder, to improve and diversify the soil.

§ 181. The sea, at this day, abounds in workshops, where myriads and myriads of little artificers are employed night and day, in readapting the earth's surface, and building up islands from its bosom for man's use.

§ 182. The sea receives from the sun its quota of heat, and stores it away for future use in the terrestrial economy:—a part of it is to be distributed by its currents; and a part by the winds, which it has to freight with the warmth-bearing vapours for the moderation of the cold in winter, and the heat in summer, in far distant regions.

§ 183. It is also the reservoir whence the fountains of all the rivers of the earth are supplied, and whence all the fertile lands in the world are replenished with rains and brooks and running water. We have seen in Book V. how, notwithstanding the unequal division of the earth's surface into land and water, there are situated far away in the interior of the continents, sterile wastes and sandy deserts of vast extent, and to which power has been given over the winds at sea, while it is the duty of the sea first to charge these winds with moisture. These burning wastes in the exercise of that power, draw (§ 165) from the sea to the land, these richly-laden winds, there to be brought under influences (§ 166) which compel them to discharge the treasures of their freight by the wayside. Thus India and many other countries owe their fertility to these connections between sea and deserts, winds, heat and vapour; they are the 'couplings' in this exquisite machinery of nature, by which sea and land are connected.

§ 184. The sea also helps to make the whole world kin, in the social as well as in the physical sense. To it, we are indebted for most of the articles of commerce, from the chief necessaries and the smallest of comforts, to the greatest luxuries of life. The clouds which crown our hills with corn, and sprinkle our valleys with fatness, are offerings from the sea, contributions to the land. By sea, come many of the articles of apparel you now wear, as well as most of the articles which decorated your breakfast table this morning. With a spoon, made of silver from the mines of Potosi or Mexico, you stirred your cup of tea brought from China, or your cup of coffee, brought from the tropics; you sweetened it with sugar from the Indies; all these came by sea; it was made also with water brought by the clouds from a bountiful sea. And, owing to the facilities of communication by sea, in contrast to those of the land, we feel ourselves to be near neighbours, and friends to the people of India, of America, and even of our antipodes in Australia, while to the people hard by in Siberia, that is shut out from the civilizing and Christian influences of communication by sea, we are as aliens and strangers. The sea opens all its borders to commerce and our sympathy; the land, on the contrary, with its mountains and fastnesses, shuts out many a fair region from the approaches of commerce, with the train of virtues and vices that make up its retinue.

§ 185. The sea is salt. Why is it salt? and whence *come its salts?* are questions often asked. They are questions to which man will perhaps never be permitted to give full answers. I can attempt nothing more than is implied, by an endeavour to point out some of the offices that, in the physical economy, have been assigned to the salts of the sea, and to show that they also are parts of the mechanism under examination. Some have held that the sea was made salt to prevent it from putrefaction. But we know that pure water is one of the most incorruptible of things:—instance all the great fresh-water lakes in the world; they never putrefy. There is no water sweeter than theirs.

§ 186. Some also hold that the salts of the sea are the ley of the earth:—that, being dissolved by the rains from the minerals of the land, washed out by the streams, and carried by the rivers to the sea, there they have been accumulating during the process of ages; for evaporation cannot take them up again. This washing out from the land may be true, as far as many of the salts of lime &c. (§ 33) are concerned, for we have seen (§ 26) how the insects of the sea act as a compensation * in the process of taking out from sea-water, for their coral formations and other edifices, the lime which the rivers are always pouring into the sea. But as to the chief salt — chloride of sodium or table salt, which these creatures do not use very abundantly, and which cannot be evaporated—the indications are, that so far from the sea being dependent on the land

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* The chronometer-maker puts into his timepiece, as an *adjustment*, a little contrivance so arranged as to *compensate* for any change of temperature to which the instrument may be exposed. Thus if the change would cause the timepiece to go either faster or slower, the *compensation* acts the other way, and keeps it exactly right; so that *compensation* means the undoing by one agency what is done by another. By such means the *harmonies of the universe* are maintained.

for salt, the land has derived most of its salt beds and formations from the sea. But whether the sea derived its salts *entirely* from the land by processes now in operation, or whether it was created salt 'in the beginning,' is immaterial to our present purpose. Suffice it to say, it is salt *now*; that the oldest records of geology, as engraved on the tablets of the rocks, or that are to be found among the fossils of the mine, show, that as far back as those most ancient annals extend, the sea was salt then; for the remains of its dead, wherever exhumed, show by evidence not to be mistaken that, from the most remote period till now, the sea has been peopled by the inhabitants of salt water. Some of them, as the coral, have still their living representatives to testify, by their present habits and in their mute way, to this fact.

§ 187. The sea derives dynamical force from its salts; i. e. these assist to give circulation to its waters. Were the sea of fresh water, there would be no Gulf-stream spreading its mantle of warmth around these islands in winter. Were the sea not salt, many parts of the ocean, that are now whitened by the steam and sails of commerce, would be sealed to navigation, with the seal of the frost king; and in this way: —

§ 188. The thermal laws of dilatation for fresh water and for salt present this remarkable contrast: as you cool them down from summer heat, they both contract:—but the fresh water, when it reaches 39°,—its point of maximum density,—ceases to contract; as you cool it below this temperature, it expands and grows lighter, till it becomes ice at 32°. So that, in winter, the coldest water, in a sea of fresh water, would be at the top. Salt water, on the contrary, continues to contract and grow heavier, as it cools, all the way down to its freezing point, which, for average sea-water, is 28°, instead of 32°. So that, in all weather colder than 39°, we should find, in a sea of fresh water, the coldest water at the top; whereas in the salt sea, in cold weather, we have the warmest water on the top; and thus climates are mitigated by reason of the salts in the sea.

§ 189. The Christian philosopher is often called upon to admire the beauty and benignity of that arrangement in nature by which fresh water is caused to expand before freezing; and by which our rivers, ponds, pools and lakes, are made to commence freezing from the top and not from the bottom. Ice and water are both bad conductors of heat; consequently in winter, our fresh-water fish in frozen ponds, are not only protected by the icy covering, but all sheets of fresh water, when that at the surface gets colder than 39°, are, by this law, enabled to keep their warmer water below, and thus protect and preserve their inhabitants. Moreover, were it not for this benign law, our rivers would commence to freeze at bottom; this would elevate their beds, causing their waters to overflow, and render uninhabitable immense districts of country that now afford smiling, safe, and happy homes to many people.

§ 190. Equal in beauty and benignity is the converse arrangement in the salt seas. There, there are no rivers to have their beds frozen from the bottom; the depth of the sea, when compared with the depths of our fresh-water ponds and lakes that freeze, makes these by comparison mere puddles in the roadway. At sea, as fast as the water cools at the top, it sinks, and warmer water from the depths below rises up to take its place; coming to the surface, it dispenses its warmth,—not like the land, chiefly by radiation, for water is not only a bad conductor and a copious holder of heat,—but by *the processes* of evaporation; for water is almost as impervious and opaque to the radiation of heat as a plate of iron is to the transmission of light.

§ 191. In his admirable lectures and beautiful experiments before the Royal Institution of London, Professor Tyndall showed how water was not only a bad conductor, but that a screen of it presents almost an absolute obstruction to the passage of radiated heat. He there simply presented, in a tasty and philosophical dress, an old fact that the shepherds and highlanders of Scotland had discovered, without knowing that it was a discovery, but which they have been utilising from time immemorial. When the shepherd there is benighted, and finds that he has to make his bed under the clear blue sky, he knows that radiation or *something else* will make him very cold before morning; therefore, to prevent the warmth of his body from escaping to the earth by conduction (§ 86), he makes his bed of the 'bonny highland heather;' and then, to prevent the heat of his person from escaping away to the sky above, he goes to the nearest brook, dips his plaid into it, wrings it out,—for a little water will do,—and then, with the wet plaid about him, he addresses himself to sleep, and is warm. So too, without knowing that he is recognising any principle of philosophy, the Esquimaux Indian builds his winter house of snow; for philosophical experiments have shown that water, whether fresh or salt, ice, snow, liquid, or vapour, is endowed with marvellous powers with regard to heat. In every shape water absorbs heat copiously, but parts with it reluctantly.

§ 192. A friend once brought me a quantity of sea water from the Pacific Ocean, and on a cold day in winter, I took a glass jar, about eighteen inches high and nine in circumference, filled it with this sea water, placed a *thermometer* and a specific gravity bottle in it, and exposed *it,—jar and all,*—to an open air temperature of 23°, that

I might mark the process of cooling and freezing. As the thermometer in the jar fell, the specific gravity bottle rose higher and higher, showing that the water, as it cooled, was contracting and becoming heaver and heaviier. This went on until the thermometer in the jar marked 27°. Then there commenced in it the display of the most exquisitely beautiful phenomena;—the fascicles of ice first formed at the bottom of the jar; and as fast as they formed, they ascended to the top with great rapidity; indeed, it was a perfect snow storm in miniature, but turned upside down. The flakes had the appearance of falling *up*. As soon as they began to form, the thermometer in the jar rose to 28°, and there remained as long as the little storm continued.*

§ 193. Thus the fact is established, that from the salts of the sea, its waters derive a dynamical force in their system of vertical circulation, which it would be impossible for a sea of fresh water to possess. Thus the salts in the sea, like the vapour in the air (§ 148), serve to promote vertical as well as horizontal circulation, for both systems are necessary to each of the two great oceans.

§ 194. The salts of the sea give it greater dynamical force for its horizontal circulation, as vapour does the air. I will endeavour to explain this;—(1) fresh water only is taken up from the sea, by evaporation; consequently, that which remains is salter and therefore heavier; on the other hand, the waters in those parts of the sea upon which this vapour is condensed and falls, are made fresher, and therefore lighter. Now, bodies of light and bodies of heavy water can no more balance each other in the sea, than a light can balance a heavy weight in the opposite scale;—or than oil and vinegar can or will, if you place them at the opposite ends of the same trough; the heavier fluid *will* rush to the place of the lighter, forcing it to seek and occupy the space deserted by the heavy; and so we have the genesis of marine currents. (2) In a sea of fresh water, no part could be made heavier by the processes of evaporation, and the difference of specific gravity due to the change of the temperature from summer heat to winter cold, not being as great for fresh (§ 188) as it is for salt water, we could have, in a sea of the former, no such currents and no such activity of circulation as we have with our own marvellous salt seas.

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* See Physical Geography of the Sea and its Meteorology. Sampson Low, Son & Co. London.

§ 195. Moreover, whatever increases or diminishes the saltness of sea water, increases or diminishes its specific gravity; it is not only summer and winter, heat and cold, rains and evaporation, that do this, but it is the insects of the sea, and the rivers also, that assist in this mighty work; whereas, in seas of fresh water, none of these influences except heat and cold would operate; and heat and cold would, as already stated, operate very feebly.

§ 196. Because the insects of the sea are microscopic and its salts invisible, let us not underrate their power and influence in disturbing the equilibrium of the ocean, and thereby putting and keeping its waters in perpetual motion from top to bottom, and from pole to pole. Each little coralline, when taken by itself and considered according to the work it performs, is not so much as a drop to the ocean. But they more than make up, by multitudes and families, what they lack in individual power. Compare the coralline with the elephant for size and strength, or with man, and then contrast the monuments constructed by the *family of mites*,—as the coral rock, islands and reefs of the sea,—with the monuments left by whole races of giants, to tell of their existence. Indeed, in some aspects, it seems to be a law of nature that the smaller the creature the greater the amount of labour required of its tribe in the terrestrial economy. Compare the great coral reefs of Australia (§ 26) with the pyramids of Egypt, or the monolythic caves of India, or the wall of China, and what are they?

§ 197. Now then, all these islands, rocks, and reefs, are so much heavy solid matter which has been taken out of the waters of the sea;—had this solid matter not been taken out, their specific gravity would have been different from what it now is. It is true, as these ingredients of sea-water are taken out in one part of the world, just as much is added by the rivers in some far distant part of the ocean. But that is the weight that drives the clock;—and this is the power that winds it up, as fast as it runs down. So, too, with the amount of common salt that is in the sea:—if it could all be precipitated and collected together, there would be enough, it has been estimated, to cover the continent of Europe all over with a layer one mile thick; and this is that other great and powerful lever which, being plied by heat and cold, evaporation and precipitation (§ 186), assists so mightily in creating, maintaining, and preserving dynamical force in the sea.

§ 198. Let us now turn to the exhibitions of this force as displayed in marine currents, first laying down this law as a principle always to be remembered,—for by having it ever present in our minds, it will prove a key by which we may unlock many a difficulty in the complicated system of currents and counter currents, which so often vex navigators.—The rule is this:—From whatever part of the sea a current runs, back to that part a current of equal volume must flow; were it not so, a current would carry away all the water from its source, and leave the bottom of the sea dry;—in such a case, we should have no such thing as a sea that knows its bounds, no such standard for our engineers as a sea-level.

§ 199. There is another physical law to be remembered, before we begin to study the currents of the sea and the circulation of its waters, for it will make the study easier; and that law is this: — whenever and wherever the waters in one part of the sea differ in specific gravity from the waters in another part of the sea,—it is immaterial from what cause this difference may arise, or how great may be the distance between two such bodies of water,—but whenever such difference does arise, the heavy water will flow, by the shortest and easiest route, towards the lighter, and the lighter, in turn, will seek the place whence the heavier came. The law that 'water will run down hill' or 'will seek its own level,' does not command throughout the domains of nature, a more general obedience than this. It is in obedience to this law, that a current is always running from the Baltic into the North Sea. The waters of the Baltic are not so salt, they are consequently not so heavy as those of the North Sea; of course, then, we have *from* the Baltic a current of fresh and lighter water, and *into* the Baltic we have an under current of salt and heavier water.

§ 200. To impress this law upon the memory, and make it still more easy of application, imagine the Arctic Ocean to be a sea of liquid oil, while the waters of the Caribbean Sea and Gulf of Mexico are as they are, quite salt. You know, and everybody knows, that oil floats on water, and that oil, therefore, is lighter than water. In such a case, everybody can understand how the waters of this sea and gulf would rush into the *Arctic Ocean*; and how the oil would rush out, spreading itself over the sea, and hastening back to occupy the space in the Gulf of Mexico that the brine had left.

§ 201. Now, if we imagine this oil to become, under the wand of some great magician, salt water as soon as it enters the Caribbean Sea, and Gulf of Mexico, while their waters, in like manner, would become oil the moment they enter the Arctic Ocean, you observe, we should have a perpetual flow of water from the torrid to the frigid zone, and of oil from the frigid to the torrid. Now, we not only have such a flow and reflow actually going on in the sea, but we have also a *great magician*, who puts it in motion. True, he does not turn oil into water, or water into oil, but as fast as the polar waters approach the Equator, and as fast as those from the torrid zone reach the frozen ocean, he does, with a mighty wand, change their specific gravity, and sends them rolling back in their ceaseless round.

§ 202. This magician is *heat*, and its wand is made of the frosts of the north, the salts of the sea, the rays of the sun, and the winds of heaven. These are everlastingly at work, altering, each in its way, the specific gravity of the waters in all parts of the sea.

§ 203. Now turn to a globe or a map of the world, and you will see,—especially if the North Pole be the centre of the map,—that the Arctic Ocean covers a very large area; that it is shut out entirely from the Pacific Ocean, except by the narrow and shallow gut called Behring's Straits, which therefore does not afford room for any great flow of waters to or from the Pacific. The chief outlet for them is into the Atlantic, through that great and wide channel, which extends from Norway on one side, to Greenland on the other, and in the middle of which stands Iceland, dividing the waters which go in, from the waters which come out of the Arctic Ocean.

§ 204. Now, if the law (§ 199) hold good, and if the 'magician' HEAT can do with his wand what it has been said he can, we should have a perpetual flow of waters from the equatorial seas into this ocean, and as constant a flow of polar waters from it into the seas of the sunny south; and this is precisely what we do have. The Gulf-stream carries the warm tropical waters into the frozen ocean of the North on this—the European—side of this channel, while the Greenland current brings out the ice-cold waters of the polar regions on the other. So abundant is this flow of warm gulf-stream waters, that in the quiet harbour of Hammerfest, in latitude 73° N. and some distance within the Arctic Ocean, they have, even in the severest winter, no ice to block navigation.

§ 205. Now turn to Plate II.: —there you will see the general system of aqueous circulation in the ocean represented. You observe first, in the North Atlantic Ocean, that the unfeathered arrows which are supposed to fly the way the waters flow, show a current setting into the Caribbean Sea, thence through the Gulf of Mexico, and so out along the shores of America,—and then in a north-easterly direction, passing between Iceland and the British Islands into the Arctic Ocean. This is a warm current, because it comes from the warm climates about the Equator.

§ 206. Now then, where is the current coming out? for according to a rule just laid down (§ 198), if there be a current setting into the Arctic Ocean, there ought to be another setting out from it; and there it is you see. Indeed there are two:—one between Greenland and Iceland, and the other coming down by way of Baffin's Bay, and through Davis' Straits, and going to the south. These currents come from the polar regions, and therefore their waters are cool; they are what are called cold currents.

§ 207. Understanding, as you now may, what the shading and the unfeathered arrows of Plate II. mean, you can trace in the South Atlantic, and the Indian and Pacific Oceans, the general flow of equatorial or warm waters towards the poles, and also the return or counter flow of polar or cold waters towards the Equator. Supposing you were sailing in a ship due west from France, over towards Newfoundland, and that you were to try the temperature of the water all the way, with a thermometer, let us see what you would find;—at first, the water would be cool, then it would be warm, and so you would say this warm water comes from a warm climate, for it could not have been made warm where it is—and in this you would be right; it therefore must, you would rightly infer, have come from the sunny south. Then, as you approach Newfoundland, the waters would become suddenly cold; 'Ah!' the observant sailor would say, 'this water did not get so cold here, it must have come from a cold climate.' And in this way, though many of these currents or *drifts* are too sluggish for the mariner to detect by his reckoning, yet the thermometer enables the man of science to detect them with the most unerring certainty. The temperature of their water tells him whence they come and whither they go. The drift of the waters of the ocean in their channels of circulation, as marked on Plate II., has been found out by discussing and comparing many thousand observations made with water thermometers, in various parts of the world, by mariners, as they pass to and fro on the great deep.

§ 208. We now come to those currents that run through the sea with sufficient velocity to be felt and appreciated in navigation. By far the most famous and remarkable of these is the Gulf-stream. It is a wonderful phenomenon; it is a river in the ocean; and is more mighty in volume than all the rivers of the earth put together. Its bottom and its banks are of cold water; its own waters are dark blue, and the line of separation between them and the cold water of its western bank is, off the coasts of the Carolinas, so sharp, that when the sea is smooth, you can see the bows of the vessel, as she enters the Gulf-stream, dashing the spray from those warm and blue waters, while the stern is yet in the sea-green waters of the bank. It has the Gulf of Mexico for its fountain, and its mouth is in the Arctic Ocean. Turn to Plate II. and mark its course.

§ 209. You see that it is fed from the shores of Senegambia, and by a current running out of the Bay of Biscay; this last skirts the coast of Africa, growing warmer and gathering its stores of heat as it goes. This current, uniting with intertropical waters, is bifurcated by Cape St. Roque in Brazil; but the larger branch keeps its course under the burning sun of the tropics to the west, and enters the Caribbean Sea at well-nigh blood heat.* With a temperature only a few degrees below this,† the Gulf of Mexico is filled with superheated waters; this gulf is the caldron whence they are to be sent into the frozen regions of the North; for remember (§ 199) that the milk-warm waters of the Gulf of Mexico and the ice-cold waters that wash the shores of Nova Zembla cannot balance each other; they are in a perpetual state of unstable equilibrium: that equilibrium, nature, with one hand, is as perpetually seeking to restore, by sending the warm to the place of the cold, and the cold to the place of the warm water, while with heat and frost in the other, she is as perpetually destroying it again. These tepid waters of the Gulf of Mexico, issue thence in a stream 3000 feet deep, and 60 miles broad, running, as it passes through the Straits of Florida, with a velocity of four miles an hour. Thence they go, galloping along the American coast to the North; they then spread themselves out over the sea, and cover millions of square miles of its surface with a mantle of warmth. The moving creatures in the sea, with every plant and animal that grows or creeps or breathes in these islands, or along its shores, are nourished in winter from the ample folds of this benign mantle.

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* In the Physical Geography of the Sea, it is estimated that the column of water daily discharged by the Gulf-stream exceeds by 3000-fold the volume that is daily borne past New Orleans by the majestic Mississippi river.

† Blood heat 96°. Highest Gulf-stream temperature 89°.

§ 210. Could the heat thus borne by this wonderful current from the intertropical seas of America be utilised, it would be sufficient to maintain in constant blast a cyclopian furnace capable of sending forth a stream of molten iron as large in volume as the discharge of the mightiest river. It is this heat that makes Ireland the 'Emerald Isle of the sea,' and which, in the midst of winter, when everything within these latitudes in America is fast bound in ice, enables the shepherds of Britain to lead their flock into green pastures.

§ 211. You observe, that after passing Newfoundland, the Gulf-stream is a little pressed down, as it were, towards the south. This is owing partly to the obstruction interposed by the Grand Banks, and partly also to the colder and heavier waters from Davis' Straits, which press down over these banks, seeking room to sink. Passing these banks, and reaching deep water, these cold and heavy waters dip under the warm waters of the Gulf-stream; they then continue their course to the south, arriving among the West Indian Islands, with a temperature in the depths of only 13° above the freezing point of fresh water. This cool water, being washed up along the shores of the intertropical lands of Spanish America, serves mightily to mitigate the heat of those burning climates. Thus the waters of the Gulf-stream take their rounds in the great and wide sea, carrying off heat where it is excessive, and bringing back cooling streams from the north, and so equalising climates by tempering the cold in polar latitudes, and modifying the severity of intertropical heat.

§ 212. Being warm, its waters teem with life. The phosphorescent animalcula of the sea swarm in it; these, its tepid waters bear even to these shores. At night, and in the storm, they mark its course across the ocean with a band of light, making a milky way in the sea, sometimes even more gorgeous, grand and imposing, than that which decks the blue vault above.

§ 213. There is still another peculiarity about the Gulf-stream:—its waters off the coast of America are salter than the waters through which it flows, and steamers cannot go as fast in it as they can in the cooler waters on either side of it.

§ 214. Now turn to the North Pacific, and you will see another Gulf-stream skirting the shores of Asia. It is called the 'Black Stream of Japan,' but it is not so strongly marked as that of the Atlantic; neither is its origin so clear. It has nothing but a narrow little communication with the Arctic Ocean; therefore, that active flow and reflow between ice-cold waters of polar seas and the milk-warm waters of intertropical oceans, *cannot be* kept up here with anything like the energy displayed in the Atlantic. The North Pacific has thrice the breadth of the northern part of the Atlantic.

§ 215. The better to comprehend the difference between these two currents, as well as the difference in the circulation of the water in these two oceans, let us contrast their physical features a little further. The waters of the Pacific are bounded on the north by the parallel of 60° nearly; those of the Atlantic have, as far as we know, free communication with the North Pole itself; certainly with the two poles of maximum cold.* Therefore as sea water (§ 188) grows colder and heavier, all the way down to the freezing point, and as the power which maintains these two currents in motion, is derived chiefly (§ 199) from the difference in specific gravity of these waters, it follows that this difference is not so great for the North Pacific as it is for the North Atlantic.

§ 216. Let us follow up this clue a little further, and it will lead us into chambers of light. The cooling surface of the North Pacific may be said to lie between the parallels of 40° and 60°, and the mean temperature of the water there is about 45°. Whereas, in the Arctic Ocean, which cools for the Atlantic circulation, the mean temperature of the water is about 28°. So much for the cold side; now for the warm.

§ 217. The intertropical waters of the Pacific do not attain as high a temperature as those of the Gulf of Mexico and Caribbean Sea, and for this reason: the Pacific grows narrower as you go north from the Equator, wider as you go south; and there are no restricted channels to interfere with the free passage to and fro of its intertropical and Antarctic waters. Its largest cooling surface is in the south; its waters circulate in largest volumes in that direction; and therefore, instead of its intertropical waters having, as they grow warm, to wait, as those of the Caribbean Sea have—for the land wont let these go south,—until they can find room, they flow off as soon as they attain a temperature which carries with it a change of specific gravity sufficient to send them off to the cooling regions of the south. In other words, the waters of the Caribbean Sea have to wait till it comes to their *turn* to get into the Gulf-stream; and they grow hot while they wait;—those in the Pacific, on the contrary, can flow off as soon as they get warm enough to move. Hence the waters of the intertropical seas of the Pacific are never permitted to attain a temperature as high as those of the Atlantic. Wherefore—since intertropical waters are not so warm in the Pacific as they are in the Atlantic;—and since the extratropical waters of the Atlantic are the coldest;—moreover, since the difference in specific gravity between these intertropical and extratropical waters is greater for one ocean than the other;—we may fairly infer that the propelling power, —i. e. the dynamical force* arising from such difference of specific gravity,—is felt with more force in the Gulf-stream than it is in the Black Stream of Japan.

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* Philosophers maintain that the coldest weather is not at the North Pole, but at two points, called the 'Poles of maximum cold;' —one near the American shore, and another near the Russian, and about 1000 miles from the North Pole.

§ 218. To make myself clear, and assist the reader to a better comprehension of what I have been endeavouring to explain, I propound a few questions based on what has been said in § 214, and in the three paragraphs that follow it. Look at Plate II.;—point out the Black

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* *Dynamical* force, the force that propels a fluid.

Stream of Japan, or the Japanese current. What is the channel or straits that connect the Arctic and Pacific Oceans? Are these straits large or small? Are they large enough to admit the passage of icebergs? No; icebergs never come through them, and are unknown in the North Pacific; but they are common in the North Atlantic (§ 215). Compare the extent of water in the Pacific, north of latitude 60°, with the extent of Atlantic waters above that parallel; roughly, what is the difference?—twice or twenty times as much? Why is not the specific gravity of the Pacific waters to the north of this parallel, as great as the specific gravity of Atlantic waters on the same side of it? Because those in the Pacific are not so cold. What is the mean temperature of the water north of 40° in the Pacific (§ 216)? This is the water (§ 199) that gives dynamical force, on the cold side, to the waters of the Pacific in their channels of circulation. What is the temperature of the Arctic waters that give the force on the cold side to circulation in the Atlantic? Specifically, which is heavier (§§ 188-192), sea-water at 45°, or sea-water at 28°? Why are the waters of the Caribbean Sea warmer than Pacific waters in corresponding latitudes (§ 217)? How is it easier for those of the Pacific to escape the heating powers of an intertropical sun (§ 217)? Now say, where have you the greater difference in specific gravity, whether is it between the cold and warm waters of the Pacific, or between the warm and cold waters of the Atlantic (§ 217)—calling in this sense, Arctic waters Atlantic waters? Again, imagine the land to extend all the way from the British Islands to South Greenland, and thence to Labrador:—in that case we should, you can readily perceive, have somewhat more of a resemblance between the North Pacific and the North Atlantic. In such a case, the Gulf-stream would be cut off from the Arctic Ocean, and its waters then, instead of running up into the frozen regions of the north to get cool, thence to return and refresh the burning climes of the south, would, ere they reached the temperature of 40°, have to turn back and seek the south to get warm again. Consequently, though the mean temperature of the waters of the North Atlantic would be higher than it is, and there would be no icebergs in it, a little reflection will satisfy any thinking mind, that, with the Arctic Ocean thus shut up, the Gulf-stream could neither have the volume nor the velocity that it now has.

§ 219. A study of Plate II. will enable the young physical geographer to point out that other great current, the adverse force of which, navigators hesitate to encounter: that current is the Mozambique current, another warm stream running from intertropical seas to Polar regions. Towards the south, whither it goes, sweeping along the eastern shores of Africa, is all sea, and there are no straits or other visible channels, after it clears the Mozambique, to guide and control either it or the return and cooler currents which come from the Antarctic seas, to restore, to the Indian Ocean, the water which this warm Mozambique current is continually carrying off from it. Nearly all on the south side of 40° S. is water; the consequence is, that instead of having, as in southern seas, sharp and well-defined currents, we have a gentle flow of warm waters towards the Antarctic Ocean, and of cool waters towards the torrid zone. Such is Humboldt's current; you see it on the Plate. It is that large flow of Polar waters along the west coast of South America. These waters, even *when they* reach the Galapagos Islands, under the

Equator, are still too cold for the reef-building coral insects to inhabit.

§ 220. We come now to currents which owe their existence also to a difference of specific gravity,—but a difference, however, which arises rather from the salts of the sea than from any thermal law; though difference of temperature here, as everywhere else, helps to make currents. The current to and from the Baltic, already alluded to (§ 199), belongs to this class; so do those in and out of the Red Sea and the Mediterranean.

§ 221. There is more water taken up by evaporation from the Mediterranean than is returned to it again by the rivers and the rains; the consequence is, a steady current from the Atlantic into that sea through the Straits of Gibraltar. This current is of salt water, and as none of its salts are taken up by evaporation, it follows, that unless, in the planning of all this beautiful and grand machinery,—the parts of which you have been studying with so much patience and profit too, I hope,—some means had been provided for getting rid of this salt, and returning it to the Atlantic again, either that ocean would, in the course of time, have lost its saltness, or the Mediterranean would have become a salt bed. Now we know that neither the one process nor the other is going on.

§ 222. The Mediterranean gets rid of these salts, and the Atlantic gets them back again, by this process:—As the waters from the Atlantic are poured into this sea, they begin to increase their proportion of salts by parting with pure water alone for the vapour, that the sun by day, and winds all the time, are continually sucking up from them. Thus, as they get further and further into that sea, the waters of this current become salter and salter, and heavier and heavier. They sink; their specific gravity being now greater than it was when they left that ocean, they begin, in obedience to laws already explained, to seek their way back into it as an undercurrent;—for the sea, like the atmosphere, abounds in currents and counter-currents.

§ 223. The first recorded indication* of this under current from the Mediterranean into the Atlantic was afforded by the drift of a Dutch ship that was sunk off Ceuta inside of the Straits of Gibraltar, by a privateer in 1712. The Dutchman must have drifted out with this undercurrent, for a few days after she was sunk by 'Mons. du L'Aigle,' her wreck was washed up on the Atlantic shore near Tangier in Morocco. Subsequent examination has fully established the existence of this current, and it is therefore a matter of fact as well as of theory.

§ 224. For the same reason there is, running through the Straits of Babelmandeb, an upper current into the Red Sea, and an under current out of it. This sea (§ 174) is in a rainless region. It receives no fresh water from the land, and the evaporation from it, is both ceaseless and immense. The quantity of salt carried into it annually by this surface current, would, if crystallised and put into the scales, weigh as much as all the water which this current carries into that sea in a period of two weeks. Hence, it is easy to show, that were there not in the depths below, some means provided for the escape of this salt, the Red Sea would long ago have been filled with a solid mass of salt.

§ 225. Of SARGASSOS or *Weedy* Seas. You observe several of these on Plate II. But the most remarkable of them all, is that in the North Atlantic. Columbus passed through it on his first voyage of discovery to America. His crew were alarmed at it, for in places it is so thickly matted over with brownish weeds, as to hide the face of the sea, presenting somewhat the appearance of a drowned meadow, and looking as though you might walk on it, without sinking more than shoe deep in water. The sargassos of the southern hemisphere are not so well marked as this, nor are they as rich in drift or floating matter.

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* *Vide* Physical Geography of the Sea and its Meteorology.'

§ 226. You observe that in both the North Atlantic and the North Pacific, the sargasso is in the middle of the pool as it were, or between the warmer current to the west, that flows north, and the cooler one to the east, which returns south. Into this sargasso of the Atlantic are carried the trees and plants and creepers that are brought down from the Andes by the Amazon, and from the Rocky Mountains by the Mississippi and its tributaries. These, with the wrecks of steam-boats that are blown up or snagged, sunk and lost on the Western waters of America, are all drifted out to the sea, and placed within the influence of the Gulf-stream. In the course of time they find their way into this sargasso. On their voyage to it,—their sea of rest,—they become loaded with barnacles and shellfish; arrived there, these die, or, loading their floating domicile too heavily, with increase of inhabitants, it finally sinks, conveying them down with it into the depths below. It may be, that thus and there, the materials of some future coal basin are being collected, arranged and deposited.

§ 227. On the Polar side of 60° S., the sea, for the most part, is literally studded with icebergs,—immense masses,—sometimes rising several hundred feet above the sea, and often presenting, in the distance, the most imposing and picturesque scenes. No such icebergs are to be found in the North Atlantic. And since icebergs are formed, not at sea, but on land, the conjecture is, that there is in the unexplored regions of the Antarctic circle, much land and heavy precipitation.

§ 228. Icebergs are formed by the accumulation of snow and ice from the clouds, and by the freezing of the rain-water, as it flows in rivers, or trickles in rills, from the hill-sides to the sea. Accumulating year after year, these masses of ice are finally broken away, either by their own weight or by the force of the storm, from their fastenings. Thus loosened, they slide down to the sea, launch themselves, and become icebergs. They serve as rivers to the Antarctic rains; they are fresh, not salt; and they carry back to the sea, all that water which the westerly winds of the southern hemisphere take up as vapour from that great southern waste of waters on the Polar side of 40° S., and let down again upon Antarctic lands. With the aid of steam and other improvements of navigation, a voyage of exploration to these unknown regions of the south, would now be neither an expensive nor a hazardous undertaking. There is there an area of twice the size of Europe, which has never been ploughed by the keel, or trod by the foot of civilised man. Only think that, in this enlightened age, there is still a portion of our planet about which we absolutely know nothing, not even whether it be land or water, and which is one-sixth as large as the known habitable portion of the globe. No attempts to explore this region have been made now for nearly the quarter of a century. Let us hope that some of the students of this little book will, when they become men, have it in their power to encourage exploration there, and thus to win for themselves the glory of adding to our knowledge concerning the Physical Geography of our planet, and of enriching commerce, no doubt, by opening up to it *new fields of* enterprise, and perhaps also of industry.

BOOK VII.

§ 229. We have now passed in review various parts of the grand physical machine which makes the earth a habitation fit for man. We see that this machinery is always in operation,—that night and day, summer and winter, seed time and harvest, it never stops for a moment. As dreadful as the storm, as mighty as the sea, it is all powerful. And the question now may well be asked, whence does it derive the power for all this mighty and marvellous work; for power to set and maintain it in motion is as necessary as it is for any piece of mechanism of our own contrivance. The hands of a watch are moved by the power or force of a spring within. Without that power, the watch cannot go; neither can this physical machine perform its office, or accomplish any motion whatever without power. The centre and source of this power is the sun. By the grace and bounty of his light and heat, plants grow, the waters flow, and animals live. Everything that moves in the sea, in the air, or on the land, is put in motion by forces that come from the sun.

§ 230. You remember (§ 47) that the atmosphere is composed chiefly of oxygen and nitrogen, with some vapour and a little carbonic acid gas, which, in turn, is a mixture of oxygen and carbon. Now this carbon is the food of plants; for charcoal, you know, is nearly all carbon. As the carbon is found in the air, the affinity between it and the oxygen is very great. It requires an immense force to overcome this affinity, and to separate these two substances. Unless the trees and flowers and fruits and plants had the force for accomplishing this, they could not grow, nor live; for while they have use for this carbon in their structure, they have none for its friend the oxygen, that adheres to it so tenaciously. Where does the plant get this power? From the light and heat of the sun. They enable it literally to tear the compound to pieces, to appropriate the carbon to the building up of its woody structure, and to send the oxygen off. Years and ages afterwards, when you come to burn this vegetable structure, whether it be in the shape of wood or coal, you liberate again the light and heat that were employed in enabling the plant to build itself up. So remember, whenever you are warmed by the coal fire, or cheered by its light, you are but setting free, for your comfort, the very light and heat that came from the sun ages and ages ago, and which were then employed,—not destroyed,—in building up the structure, be it coal, gas, or wood, which you are now consuming. And when you see a bit of gun cotton exploded with more terrific effect even than gunpowder, recollect that the violence of the explosion is caused by the sudden liberation and clashing together of those very elements which the tender cotton plant had, in the process of its growth, gently to tear asunder, and pull apart in order to construct its own little fibres.

§ 231. That mechanical and physical power can be stored away, even by man, to be used at pleasure, is patent; it is familiar to us all. The water in the mill-pond is power so stored; but it is power derived as directly from the sun as is the heat from the coal which drives the steam-engine. The sun pumped up from the sea the water in the miller's pond, and by its might, *carried it up* into the clouds; the heat of the sun propelled the winds which bore this vapour thence to the land. So, too, when you wind up your watch, you store power away in the spring to last for a day, or until the watch runs down. That power came from your own muscles, it is true, but whence did they obtain it? From your food, which got it from the sun. The sun is continually storing away force, in the shape of heat, to be brought into play, and to do its work in the physical economy of the earth at some future time.

§ 232. You can understand now, how the land, with its vegetation, may absorb for a time, a larger portion of the sun's rays, and store them away for future use, than the sea can. The heat that would be made by burning, in winter, all the vegetable growth that takes place in summer, whether in field or forest, would indicate the amount so bottled away annually by the earth. But this quantity, though so large to us, is really, when compared with the bountiful supply from the sun, infinitesimally small.

§ 233. The power of the sun, as the source of every motion—except that of the tides—which we see on earth, is thus described by Professor Tyndall, in his work on 'HEAT,' wherein all motion is considered as but another expression for heat of the sun:—'Every mechanical action on the earth's surface, every manifestation of power, organic and inorganic, vital and physical, is produced by the sun. His warmth keeps the sea liquid, and the atmosphere a gas, and all the storms which agitate both are blown by the mechanical force of the sun. He lifts the rivers and glaciers up the mountains, and thus the cataract and the avalanche shoot with an energy derived immediately from him. Thunder and lightning are also his transmuted strength. Every fire that burns, and every light that glows, dispenses light and heat which originally belonged to the sun. In these days, unhappily, the news of battle is familiar to us, but every shock and every charge is an application or misapplication of the mechanical force of the sun. He blows the trumpet, he urges the projectile, he bursts the bomb. And remember this is not poetry, but rigid mechanical truth. He rears, as I have said, the whole vegetable world, and through it the animal; the lilies of the field are his workmanship, the verdure of the meadows and the cattle upon a thousand hills. He forms the muscle, he urges the blood, he builds the brain. His fleetness is in the lion's foot, he springs in the panther, he soars in the eagle, he slides in the snake. He builds the forest, and hews it down; the power which raised the tree and wielded the axe being one and the same. The clover sprouts and blossoms, and the scythe of the mower swings by the operation of the same force. The sun digs the ore from our mines; he rolls the iron, he rivets the plates, he boils the water, he draws the train, he not only grows the cotton, but he spins the fibre and weaves the web. There is not a hammer raised, a wheel turned, or a shuttle thrown, that is not raised and turned and thrown by the sun. His energy is thrown freely into space, but our world is the halting place where this energy is conditioned. Here the Proteus works his spells; the selfsame essence takes a million shapes and hues, and finally dissolves into its primitive and almost formless form; the sun comes to us as heat; he quits us as heat; and between his entrance and departure the multiform powers of our globe appear.'*

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* Section XII. Heat considered as a Mode of Motion, by *John Tyndall*, F.R.S. &c. London: Longman, Green & Co.

BOOK VIII.

§ 234. Having studied the principal parts of the wonderful machinery from which nature derives those aspects that are peculiarly interesting to the Physical Geographer, and having examined some of the offices that, in her admirable economy, have been assigned to those parts, we are now prepared to take a survey of the whole together; to note peculiarities to which attention has not been called; to draw new contrasts; and to form conclusions which, so far perhaps, have escaped us. Turn again, therefore, to a common terrestrial globe; or, in default of that, to a map of the world.

§ 235. The northern hemisphere, you observe, has, as you were told in Book IV., not only most land, but its shore-lines are also better articulated with water surfaces. Northern oceans stretch out long arms; with these they reach far away into the recesses of the land, and there form seas, bays, and gulfs, as the Baltic, the Mediterranean,—which separates Europe on the north, from Africa on the south, and washes the shores of Asia on the east;—as the Red Sea, which, at the Isthmus of Suez, cuts the land of the Old World almost in two, as the Caribbean Sea, in the New World, does at the Isthmus of Darien. Then there is the Persian Gulf, the Arabian Sea, the Bay of Bengal, the Gulf of Siam, with those various seas, gulfs, and bays, which indent, in such a remarkable way, the eastern and northern coast line of Asia, the western and northern coast line of Europe, and the western, northern, and eastern coast line of North America. Now, contrast these irregularities of coast lines with those of southern shores. With the exception of the Gulf of Carpentaria, on the north coast of Australia, southern oceans are almost without arms, and southern lands without tongues to give varied articulation to shore-lines. The shore-lines of Australia, of South America, and Africa, are almost straight; compared with those of the northern hemisphere they are rigid to a degree.

§ 236. These articulations are not without a purpose, nor are northern seas made to stretch out their arms in vain. Among the manifold offices for which they are required to assume this position, is the mitigation of climates and the giving of fruitfulness to the land. These arms, spreading out into magnificent sheets of water in the midst of our continents, serve as relays, as it were, of vapour for the winds, which, as they blow in their mystic circuits, are furnished by these sheets with fresh supplies for watering and making fruitful, lands that otherwise, perhaps, would be mere arid wastes.

§ 237. Thus the North-east Monsoons get from the Bay of Bengal the vapours which the Eastern Ghauts condense into rain for the East coast of the Indian Peninsula. So also they pump up out of the Arabian Sea water for the rivers in Eastern Africa. Were it not for the Red Sea, Egypt would have no Nile. And, but for the immense evaporating surface afforded by the Mediterranean (§ 222), in the midst, as it were, of the Old World, many parts, both of Europe and Asia, that are now abundantly watered, and very fruitful, would be lands of drought and stinted herbage.

§ 238. The benignity of this arrangement deserves *attention* for a moment. You are aware that the winds can hold comparatively but little moisture at a time; ordinarily about one quarter of one per cent. of the air you breathe is vapour of water. Whenever the air is fully saturated with vapour, as it often is, any, the least, lowering of the temperature, will wring out portions of this vapour, first as cloud, then as rain. The winds, therefore, cannot bring at one load vapour enough from the Atlantic to water the whole of Europe and the interior of Asia also. There must be relays for them. The marine current through the Straits of Gibraltar fetches a constant stream of water into the Mediterranean for this purpose. Running in from the Atlantic (§ 221), it spreads itself out over that classic sheet of water to supply the winds as they come with fresh loads of vapour. Satisfying these with moisture, the waters of this current become heavier, because salter than before; they sink, and bearing back with them in the depths below, mud and silt which the rivers are continually discharging into that sea, with other feculences that are found there, they sweep them off to the ocean, and so help to keep the Mediterranean from silting up. Thus the bottom of that sea is scoured out by waters which are brought in on the surface to supply the obedient winds with moisture. As these travel on in their circuits, dispensing showers as they go, they come to other relays, as the Caspian Sea and numerous other seas and lakes of the interior, which have no oceanic drainage, and from which the water taken up by evaporation is exactly equal to the quantity returned to them again by the rivers and the rains. Thus the winds take up out of the Dead Sea just as much water as the Jordan discharges into the Dead Sea, for the Jordan runs into that sea as the Volga and other rivers do into the Caspian; and yet these seas are not full, neither are they drying up. So also does the current (§ 224) through the straits of Babelmandeb supply relays of vapour for the winds which sweep over the Red Sea. The vapour that rises from that sea is dropped down as rain upon the hydrographic basin of the Nile.

§ 239. In the Southern Hemisphere, on the other hand, there is so much water, so little land, in one mass, as compared with the vast area occupied by Europe, Asia, and North Africa, that in the physical economy no such arrangement as highly-indented shore lines, outstretched arms of the sea, deep bays and gulfs, with their relays of vapour far away in the interior, seems to be required. Indeed, there is scarce land enough in one body there to admit of any great Mediterranean, or of deep bays, long gulfs, or extended Caspians. Southern lands, when compared with Northern, are arranged in such small masses that almost every wind that blows upon them is as fresh from the sea, as are those which furnish the sources of the Amazon, the Mississippi, the Amoor, the Lena, the Obi, and the like, with their never-failing supplies.

§ 240. Continuing this contrast (§ 234), as presented by the physical aspects of the two hemispheres, you observe that the Northern has not only a more varied articulation of shore-line, but it is richer also in inland seas, as the Caspian, the Dead Sea, and the Sea of Aral; also in lakes, rivers, and mountains, and in steppes and deserts. Neither the steppes of Asia nor the deserts of Africa have any counterparts in the Southern Hemisphere. The river Amazon is common to both hemispheres, and with the exception of the Rio de la Plata of South America, there is in that hemisphere no hydrographic basin,—as the whole area drained by any river *is called*,—sufficiently large to collect water enough for such mighty and majestic streams as are found in North America, in China, India, the Russian possessions, and Europe.

§ 241. The chain of the five great American lakes,—beginning with Superior and ending with Ontario,—is computed to contain about two-thirds of all the fresh water in the world. It would take the Mississippi 100 years to discharge into the sea as much water as these five lakes at present contain. Yet the Mississippi and its tributaries give sea-drainage to the rain that falls upon a district of country that embraces an area of no less than 982,000 square miles. The Amazon is connected with the Orinoco through the Cassiquaire, which, striking against a rock, has its waters divided, one branch flowing north to join the Orinoco, the other turning south into the Amazon. The Tocantins also joins the Amazon, and forms its Delta—the great Marajo. Treating the country that is drained by these three streams as belonging to the same hydrographic basin, we have here in one body, an area of not less than 2,048,000 square miles. The La Plata and its tributaries give drainage to an area computed at 886,000 square miles.* These three river basins are in America, they are the largest in the world, and together include an area greater than the whole of Europe. No such water sheds are to be found either in Australia or Southern Africa. Those lands lack both rain-fall and area of hydrographic basin to collect water enough for such mighty rivers as those that irrigate the continental masses of the North.

§ 242. Allusion has been made (§ 240) to inland seas. In these we have a beautiful system of adjustment, by which they are enabled to preserve their level; for there are one or more rivers emptying into each one of them. The Jordan, for instance, discharges its waters into the Dead Sea, and, as there is no visible outlet for its waters, and as the Dead Sea does not get full, there must, it was formerly conjectured, be a subterranean channel by which the waters of the Jordan make their escape to the Mediterranean. But my friend Commodore Lynch, of the Confederate navy, has shown, by careful survey, that the Dead Sea is 1300 feet *below* the level of the Mediterranean. The Caspian is 80 feet below the general sea level also, and the mighty Volga pours its floods into that inland sea, but neither does it ever get full. Now there is nothing more wonderful in this than there is in the fact that the great and wide sea itself never gets full, yet the mightiest rivers run into it. The reason is simply this: the rivers and the rains return to the sea only the waters that the winds take up and carry as vapour and spray away from the sea. And the adjustment between them and these inland seas consists in this:—The surface of these seas has, in the course of ages, been gradually lowered by evaporation, until the evaporating surface became exactly of the area required to give off as much water in the shape of vapour as is returned back from the land into these seas again. If any such inland sea gave off less, it would, in the process of time get full and overflow;—if it gave off more, it would in the process of time become dry.

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* Maury's Physical Geography of the Sea and its Meteorology. London: Sampson Low & Co.

§ 243. Take the Dead Sea as an illustration. Time was,—in the remote ages of geology, when (§ 178) the climate of England was perhaps intertropical,—that the Dead Sea did have oceanic drainage. Travellers there tell us of the dry bed of a river running off in a southwardly direction, as if to reach the Red Sea through the *Gulf of* Akaba. If there ever was such a river, then the surface of the Dead Sea must have been at least 1,300 feet above its present level, and its waters then must consequently have covered much country that is now dry land. If such were ever the case, the evaporation from the expanded surface would necessarily lift more water than it now does from the contracted one. If the quantity thus lifted were in excess of the quantity flowing back to it through the Jordan, the sea would be pumped out by the winds until the surface exposed to evaporation should, by contracting more and more, give off a quantity of water, as vapour, exactly equal to the quantity returned from the drainage of the land again. All sheets of water without natural outlets seem to have had their levels reduced by this process, and until an equilibrium has been established, between what is taken up by evaporation and what is returned again by drainage and precipitation.* This process of adjustment is well marked about the Caspian Sea, for its margin is fringed with salt-beds and plains that have been left there during the process of evaporating that sea down to its present level. The same is the case with the great Salt Lake of America, and with all other salt lakes, great or small, only in many cases all the water has been evaporated off from them before attaining the equilibrium. In such cases the bed of the lake or pond is left as a salt-bed to testify that the basin in which it lies, was once the bed of a salt sea.

§ 244. In this aspect, the Physical Geographer considers every sheet of water that spreads itself out in the interior of continents, as a relay for the winds; they pump up water from these reservoirs to feed the springs which run among the hills; just as much as is pumped up by evaporation, just so much do the rivers and the rains pour back. This is the case whether the reservoir contain sweet or bitter waters.

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* Precipitation or the condensation of vapour in the air; whether it descends as rain, hail, snow, or dew, it is all precipitation.

§ 245. Nor is this the only light in which the true Physical Geographer regards these inland sheets of water; for, in studying them, he discovers also other uses for them in the terrestrial economy. They not only add loveliness to the landscape, but they serve as a refuge or dwelling-place to many of God's creatures; they also serve as reservoirs for supplying the rivers and vegetation with water, and giving out moisture during periods of drought. They also prevent floods in the rainy season, and they equalise the flow in the dry. Thus the great American lakes are reservoirs—fountains—of the Niagara and St. Lawrence; summer and winter, in times of the heaviest rains, and in periods of the severest drought, these rivers are not affected by the one or the other. Apparently the quantity of water discharged by them is always the same.

§ 246. As a rule, all the great rivers of the world have their head waters in lakes, their tributaries being made up of rills innumerable, each one of which may be traced back to its source among the hills. The Amazon, the Mississippi, the Nile, and all the rivers of that class, have lakes, not springs, for their sources. The Lake Morococha gives rise to the Amazon; Itasca and innumerable others to the Mississippi; Nyanza to the Nile.

§ 247. The extreme rise and fall of the Mississippi up towards its sources, even as far down as Lake Pepin, does not exceed six or eight feet; but, opposite Memphis in Tennessee, it has a rise and fall of eighty feet. This is because its lower tributaries have no lakes or reservoirs into which the floods may be collected, and stored away, as it were, to be carried off gradually. When the rain pours upon water-sheds that have no lakes or large reservoirs, the springs gush out, the branches overflow, and the whole drainage of the water-shed is at once delivered to the tributary, to be forthwith poured by it into the main stream itself. Thus in spring, the melting of the snows on the Rocky Mountains, floods the Missouri. Now, when it happens, as it often does, that simultaneously with the Missouri flood, another caused by heavy rains comes down the Ohio, or the Arkansas, or the Red, or, as is sometimes the case, down them all, there is a mighty flood in the lower Mississippi, causing it to overflow its banks, to break through the levees, form crevasses, and, by flooding the country, to do an immense amount of damage.

§ 248. But for the supply of water stored away in Lake Victoria Nyanza, and treasured up as snow on the Mountains of the Moon and other high hills in Africa, Old Nilus himself would, in the dry season, cease to flow, and Egypt would become a barren land. But it so happens—nay, it is so arranged—that the rainy season on the upper tributaries of the Nile, which are in the Southern hemisphere, occurs generally at the very season when the snows that fill its other tributaries, are not in thaw, or when the rains on the north side of the Equator have not set in. It takes some time for this flood from the southern hemisphere to travel down, but when it reaches the lower Nile it causes it to overflow its banks and fructify the land in the most remarkable manner. Now it sometimes so happens with the Nile, as it does with the Mississippi, that when one set of tributaries is flooded with snow-water, another set is also filled to overflowing with rain-water; and thus there is a tremendous overflow, and great damage to husbandmen, as there was in Egypt, in the annual overflow of 1863.

§ 249. In the Amazon, those conditions which secure uniformity as to flow of water in the river, are varied. Though this river has its source in a lake on the Andes, and though its margins in the low country are often fringed with swamps and reservoirs (§ 247), yet its principal reservoirs are in the equatorial cloud ring (§ 104). One-half of the year its northern tributaries are flooded; then its southern tributaries are at their lowest stage, and *vice versâ*; so that the main stream itself is always discharging the floods either from one side or the other, and the two sets of tributaries cannot be in flood at the same time.

§ 250. But, to return to the two hemispheres:—There are still other contrasts which patient observation and laborious research have brought to light. One of them is this, and it seems paradoxical enough, viz.: (§ 1) Notwithstanding there is in the Southern Hemisphere more sea, and consequently more evaporation (§ 82), there is in the Northern Hemisphere, more rain, and consequently more rivers. That is, in regarding the atmosphere as a grand machine, propelled by the heat of the sun, and having the most complicated but sure movements, the Southern Hemisphere, with its great watery expanse, now presents itself as the boiler, while the Northern, with its vast extent of land, acts as condenser to the mighty engine.

§ 251. Comparing latitude with latitude, we find that southern seas are, as a rule, cooler than northern. The reason is obvious: the cold latitudes of the south are all water; of the north, they are mostly land. The Antarctic regions are entirely open to southern oceans and their flow of equatorial waters; northern seas, on the other hand, are shut out from the flow of inter-tropical waters, except by those comparatively small channels which reach to and from the Arctic Ocean; so that, as the warmer waters flow north or south from the Equator, those that go south cool faster, by reason of the larger cooling surface in the extra-tropical regions of that hemisphere.

§ 252. Especially is this the case in the Atlantic Ocean, for while its cooling surface about the Antarctic regions—indeed we may say south of the parallel of 45° S.—is so large, its heating surface on the north side of the Equator, in the torrid zone, is twice as large as it is on the south side. It therefore heats faster and cools slower in one hemisphere than it does in the other.

§ 253. As the Southern Hemisphere has more water, a larger evaporating surface is exposed to the sun and the winds there, than in the Northern Hemisphere; consequently the southern atmosphere,—especially that part of it that lies on the south side of the parallel of 45° S.,—is more heavily charged with vapour than that in the corresponding region of the Northern Hemisphere; and, as vapour is so very much lighter (§ 61) than air, it drives off portions of the air that overhangs that great expanse of Austral waters, causing the barometer to stand lower there than it does in the corresponding Boreal latitudes. In another place, the Austral winter has been shown to be also longer (§ 82) than the Arctic. But, while the Southern Hemisphere has less daylight than the Northern, southern seas are neither vexed by storms nor harassed by calms, so much or so often as are those of the Northern Hemisphere. The reason is, there is more land on our side of the Equator, with its mountains, deserts, and forests to interrupt and obstruct the movements of the air. Meeting with these obstructions, it is directed from its *course*, or brought to a stand-still, until, accumulating, it finally, like pent-up water, bursts forth, strewing its path with shipwreck and disaster.

BOOK IX.

§ 255. We have now completed our survey of the inorganic World, and finished the study of those influences which make the landscape what it is—wherever and whenever we look out upon it,—and as we behold it unenlivened by the presence of man, bird, or beast. Let us, in this Book, contemplate the face of Nature as it is, and study the surface of our planet as the abode of man, as the scene of vegetable life, and the habitation of all living creatures, whether of the land, the water, or the air.

§ 256. Every plant, tree, and animal to be found in either of these three elements, has what is called its GEOGRAPHICAL RANGE,—that is, the limits beyond which it is death to venture, but within which Nature supplies all the physical conditions suitable to its well-being. For the vegetable kingdom, which supports the animal, these conditions embrace, not only soil and climate, but winds, and sometimes, also, the co-existence of insects, and occasionally even of other animals whose instrumentality is required to assist the plant in the propagation of its species. Were it not for the gad-fly to fructify the fig-tree, we should be without its delicious fruit; bees and birds are required, as they suck the sweets or gather honey, to carry pollen from one flower to another, and so to enable certain plants to bear fruit. Again, there are other plants, such as the cereals, and a variety of others that grow on our farms, and furnish our table with vegetables, that, notwithstanding soil and climate and all physical conditions that nature can supply, would die out and disappear from the face of the earth were it not for man. Most of the domestic fruits and plants, such as corn in all its varieties, are of this sort. Comparatively few plants that grow near the Equator will flourish in the climate of England; it is unsuited to the sugar-cane, the coffee-tree, the cotton-plant, the date, olive, and the like. Their geographical range does not extend to the latitudes of England.

§ 257. There are families of insects which subsist on a single plant, and no other; of course, where that plant is not to be found those insects are absent. Nature is said to have quartered no less than forty different kinds of insects upon a single plant, as the common nettle.* Of course, then, in countries that lie beyond the GEOGRAPHICAL RANGE (§ 256) of the common nettle, none of these insects are to be found. Upon certain kinds of insects, other insects live, to be preyed upon in turn by beasts, birds or reptiles, which in their turn also become food for worms, or are devoured by larger animals. So it is readily perceived, that from first to last, there are myriads of links and thousands of chains, which connect together, bind up, and make reciprocally dependent upon each other, every subject in the two great organic kingdoms.

§ 258. To each individual with its family in these wide domains, whether of the animal or vegetable kingdom, Nature has prescribed duties in her economy, and assigned geographical limits. Only to man, the lord of all, and to the dog, his companion and friend, has she set no bounds, but *given* a geographical range from pole to pole. They roam the earth together, and in company go where they list; where mother earth fails to supply them with the means of subsistence they, with the intelligence of the one assisted by the sagacity of the other, gather it from the air or the water wherever it is to be found. This true friend of man, and faithful creature, continually reminds us by its instincts, that it was endowed with certain of them, not only for man's use, but for his pleasure and amusement also. Take as an example the setter and the pointer dogs. These two species display instincts which are not used by that animal either in attack or defence, or in the procuring of food. But man, in the ennobling sports of the field, turns them with marvellous relish to his own pleasure and advantage.

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* Mrs. Somerville's Physical Geography.

§ 259. So also is there a vertical as well as horizontal range for every organic creature under the sun. The inhabitants of the sea cannot live beyond certain depths; nor the birds of the air, beyond certain heights; nor man beyond the tops of the highest mountains; nor can vegetation, except such as can grow on or under ice or snow, soar as high. As a rule, the temperature decreases 1° for every 300 feet of perpendicular height. So that, as the traveller ascends a high mountain,—such as Chimborazo, for instance, which is upwards of 21,000 feet high, and is situated near the Equator in South America,—and reaches the height of about 16,000 feet, he comes to the limits of perpetual snow. This line, called the snow line, comes nearer and nearer to the surface of the earth as you approach the poles; until finally it reaches the sea-level in the Arctic and Antarctic regions, where the ground is perpetually frozen. The mountains in Scotland—some of them—are high enough to reach the snow-line, though the heavy precipitation over these islands, makes it higher than by the rule it should be.

§ 260. Vertically, the sea is most thickly crowded with plants and densely inhabited by moving creatures between the surface and the depth of 100 feet. Here the plants, many of which are most beautiful in colour, and bizarre in form, begin to disappear. As in the air, so in the ocean, the animals are permitted to have a wider range than plants. Animal life in the sea extends to the depths of 1000 feet; and some philosophers go so far as to say, down to the very bottom and bed of the ocean.

§ 261. It was not until our own day that attempts were systematically made to obtain specimens of bottom from the deep sea. The author had the good fortune, some years ago, to win the power of setting on foot a regular series of deep-sea soundings. These resulted in the discovery of the celebrated telegraphic plateau, a raised bed in the Atlantic, extending from Ireland to Newfoundland, and on which, in 1858, a telegraphic cable was laid from Valencia in Ireland to Trinity Bay in Newfoundland. It however failed to work almost immediately.

§ 262. During this series of soundings, the bottom of the ocean was tried in various places, with reported depths, varying from 1000 to not less than 30,000 feet; but the deepest specimens of soundings that were obtained came from the North Pacific Ocean, at the depth of a little over three miles and three-quarters (19,800 feet).* Whether from the Atlantic, the Pacific, or the Indian Ocean, the Red Sea or the Mediterranean, all these treasures from 'the ooze and bottom of the sea,' when placed under the microscope of Ehrenberg and Baily, told the same story; namely, that the bed of the ocean is a great charnel house strewed about and covered up, to the depths perhaps of many feet, with the remains of its own dead. Most of their skeletons are mere mites of things, far too minute, as individuals, for the naked eye to comprehend; but, brought up in masses, which the officers took to be mere lumps of unctuous clay, it was not difficult for the microscopist to resolve them, and to make drawings of the shells which they had inhabited. With the remains of these little creatures, the Gulf-stream, throughout its course, has strewn the bed and bottom of the Atlantic, dropping them down as gently as falls the snow-flake in a calm. They bear no marks of abrasion, but suggest that at the bottom of the deep sea there is no running water, nor anything to disturb the almost perfect state of repose that reigns there.

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* Vide p. 308 of Physical Geography of the Sea and its Meteorology.

§ 263. The insects—including under this term all that are too small to be recognised as beasts, or birds, or fishes—exceed in numbers all the other inhabitants of the sea, and land, and air; and in all three of these elements, they most abound within the inter-tropical latitudes. There they fill the air with their hum and make the landscape to glow and sparkle with fire and flame. At night, as the navigator ploughs through intertropical seas, his keel leaves a broad bright wake to mark its passage, owing to the immense multitudes of phosphorescent animalcula it has disturbed in its silent path. And, when the sun sets upon intertropical America, where insect life most abounds on land, the forests and plains resound with their hum, that is said to have been heard by mariners several miles out at sea.* There, too, the curtain of the night is spangled with the most glittering jewels of the insect world. Fireflies, bearing their green, red and white lanterns, and showing them now as fixed, now as occulting lights, cause the darkness to glow and sparkle again with brilliant and countless flashes. On certain occasions, the ladies in some parts of South America deck their hair and ornament their dress with a particular species of these luminous insects, in preference to jewels. In Brazil, the insects present the most brilliant and beautiful colours, surpassing even the plumage of the birds and the flowers,—gorgeous as these are. Persons there support themselves by catching these finely-coloured insects, and making of their shields, wings, and legs, artificial flowers of the most exquisite elegance, taste, and beauty.

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* Mrs. Somerville's Physical Geography.

§ 264. There are said to be no less than 300,000 kinds of insects that are already known; and when the physical geographer learns that these creatures most abound in inter-tropical America, he need not be told that there the powers and wealth of the vegetable kingdom are displayed in greatest variety, profusion, and glory. Small as these creatures are, and individually insignificant too, we must not regard them as of no use in the world. Every family of them has no doubt its work to perform in the economy of nature. We may not discover what is required of each particular tribe, but we see the work of many of them, and in such cases we are left in no doubt as to the part borne by them in making the face of the earth what it is. We have seen the little coralline (§ 30) building up islands in the sea, and we may now behold these islands as the scene of many a happy abode for man. If we look at home, we may see another of the numerous cases in point that could be named, and which is afforded by the common earth-worm. One of its offices in the physical economy seems not only to be to make the soil fertile, but to help also to keep it fit for cultivation. It bores through the rich earth, and, in doing so, makes it not only more permeable to air and water, but it passes bits of the soil through its own intestines. In this process, the productiveness of the land is greatly increased. Every particle of soil in these realms has, from first to last, had its fertility increased by the labours of this crawling thing.

§ 265. Insects are often of the most tender and delicate structure. They cannot endure extreme vicissitudes of climate. They burrow in the earth, or hide in the bark and wood of trees, to escape the frosts of winter. Indeed, high mountains, on account of the low temperature of their snow-clad heights, seem to present impassable barriers to most of the insect tribe. Hence the marked difference often observed in the insects on opposite sides of the same mountain range.

§ 266. All the larger marine animals of the Northern Hemisphere are said to differ more or less from their congeners of the Southern. To those of the extra-tropical regions, the Equator is as a sea of flame which they cannot pass. The right whale of the Northern Hemisphere differs in its physical aspects from his fellows of the Southern Hemisphere. He cannot pass to them, nor they to him. Those of the North Pacific and North Atlantic are alike. It is the practice of whalemen to name and date their harpoons, and many years ago a whale was captured in the North Pacific in which was found, when he was brought to the 'winding tackle' for 'cutting in,' an iron that was thus known to have been thrown into him off the shores of Greenland. Now, since he could not cross the Equator to pass either Cape *Horn* or the Cape of Good Hope, and so enter the

Pacific, the inference was that he must have come through the Arctic Ocean, and thus we had one of the first practical indications as to the existence of the famous North-west Passage.

§ 267. Attention may be here called to the fact, that the sea is without music. To none of its inhabitants has the voice of song been given. The same remark applies to the beasts of the field and the reptiles of the earth. They hiss, they make a noise, they utter their sounds,—those that have voices,—either in the tones of anger, affection, or complaint. The gift of music and the faculty of song appear to be peculiar almost to the bipeds—to man and the birds.

§ 268. Turning now to the land and its flora, we can see why precisely the same plant that is indigenous to the warm climates, the bright skies, and teeming soil of the Equator, should scarce find support in the stingy soil and frozen regions of the Poles. In the equatorial region the palm, with the whole of its picturesque tribe, the bread-fruit tree, and the orange, the banana, the fig, and grape, the coffee plant, the sugar-cane, the gum and spice-yielding trees, the banyan and ferns, with creepers, climbers, parasites, and air plants innumerable, delight to grow. As you approach the Polar regions, the vegetation dwindles down to mosses and lichens, until finally these disappear, giving place to the protococus nivalis, which has its habitat in the snow and on the crimson cliffs of Beverley, in the Arctic regions.

§ 269. Of cereals, and what may be called the *social* plants, inasmuch as they require cultivation, and, therefore, the assistance of man to enable them to produce fruit, barley has the widest geographical range. It follows the grasses up into those severe climates where the subsoil is perpetually frozen. In parts of Siberia even during the hottest periods of summer, the thaw reaches not beyond the depth of a few inches; yet the cattle find pasturage and the people grow turnips upon such a soil.

§ 270. Some of the plants named (§ 268) overstep the tropics, and flourish also in the temperate zones; the fig, the orange, the banana, the sugar-cane, &c., belong to this class. Others, as the olive, currant, cranberry, tea, and the like, are exclusively extra-tropical; but those productions of the torrid zone, which flourish well in the temperate zones also, and which have the widest range beyond the tropics of Cancer and of Capricorn, are the cotton plant, wheat, maize, indigo, the vine, tobacco, rice, &c. Some of these have a geographical range that extends from the Equator well nigh up to the Polar edge of the temperate zone.

§ 271. Of all the cereals, maize or Indian corn has been the most potent in influencing and facilitating the colonisation and settlement of the New World by the Anglo-Saxon race. Of all the plants, it is the most valuable gift of America to man in his ruder state. Its geographical range is not so wide as that of wheat. Yet without Indian corn it is difficult to conceive how the continent of North America could have been reclaimed from the wild beast and the savage,—could have been subdued and brought under cultivation as rapidly as it has been. Persons accustomed to it, especially those of the labouring classes, prefer the bread of maize to that of any other cereal; as an article of food, it is palatable, wholesome, and nutritious. It may be served in a great variety of shapes, and is eatable as soon as the ear reaches the milky state, which it does in six or eight weeks after planting. Whole divisions of the armies of the Confederate States of America sometimes go on forced marches, with nothing in their haversacks but a little 'parched corn,' that is, the grains of the ripe ear roasted as the cook roasts the coffee berry. Some varieties of this corn is fit for the table in six weeks after the seed has been put into the ground.

§ 272. Now, when the hardy pioneers from Virginia and Carolina* first crossed the Alleghany Mountains, and entered the Mississippi valley, they found the country filled with hostile tribes of Indians, and its forests abounding with the most savage beasts and poisonous reptiles. The steam-boat was then unknown; of roads there were none; in crossing the mountains, these hardy adventurers took the path of the buffalo for their guide, or 'blazed their way' through the forests, that those who came after them might know where to follow. The outfit of the emigrant in those times consisted chiefly of his rifle, his axe, and a sack or two of Indian corn. The magnificent maple trees of the forest afforded him SUGAR; the 'deer licks,' SALT; with the skins of the wild beasts, he clothed himself; and their flesh was his meat. And as for bread, there was to him nothing like the beautiful, the bountiful Indian corn. This grain has the marvellous power, when ripe, of housing itself; a power which, considering the pioneers into that wilderness had no barns, made it truly invaluable. It is covered with an outer coating of 'shuck' or thatch, that enables the ear to keep its grains dry in the wettest weather; its stalk is stout and strong, bearing the ear from month to month, and until such time—even though it be the succeeding spring time—as it may suit the convenience of the husbandman to pluck it. And then, for making into bread, it requires no leaven; a cake may be made of it and baked in the time that it takes to cook a potato.

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* The celebrated pioneer Daniel Boon, who first established white settlements in Kentucky and Tennessee, and led the way for the Anglo-Saxon race into the valley of the Mississippi, was a North Carolinian.

§ 273. When the emigrant with his family reached, in these wilds, the place which was to be his future home, his first care was to build a log cabin as a dwelling; next to fell a few trees, so as to make an opening through the leafy canopy, by which the rays of the sun might reach the soil. This was his corn-field, which he cultivated, gun in hand. In a few weeks it produced ears fit for the table, and so bread was provided for him in the wilderness. The vegetable health of the maize requires that the tender ear should stand erect, until it has passed the milky state; then, that it should bow and be pendent from the stalk until it is gathered.

§ 274. Now, it will be observed that in the account of this cereal, which has had such an important influence upon the progress of settlements in America, the emigrant has had no time to build barns. It was as much as he could do to barricade himself and family against the savages and the weather, and to clear the land. An ear of this corn is not like the ear of wheat or any other corn, yielding only two or three thimblesfull of grain at most; a single ear of Indian corn will sometimes yield more than a quart of grain, and, as it comes from the ear, it is ready for consumption, for it requires no winnowing.

§ 275. Moreover, in America the climate is such, and the display there of the vegetable forces is so vigorous, that when the corn of wheat, barley, oats, or rye is ready for the sickle, it will not wait more than a *few days*. It must be harvested immediately, and then housed, or the crop will sprout in the shock, or heat and be lost. The settler in a wild country and among hostile Indians, could not gather such a harvest; and if he could, it would be of little worth without mills to reduce it to flour. The corn of maize would await his leisure, and it may be used without grinding. In America, Indian corn is called 'the poor man's friend.' It thrives best in continental climates, where the heat of the sun is far more intense than it is here in England. Its geographical range extends from the Equator to about midway the temperate zones, its favourite climates being found between the parallels of 20° and 45° of latitude.

§ 276. Cotton, another plant to which a world-wide and special importance is attached, has a geographical range, not so wide as that of Indian corn, it is true, but nevertheless wide enough to embrace within its limits two-thirds of the surface of the earth. In any climate between the parallels of 40° N. and S., the cotton-plant will grow, and mature its wool in the open air. Nevertheless, some of the climates within this range suit it better than others. The cultivation of this plant,—the fabrics of the wool of which constitute the principal article of clothing for the human family,—has, by reason of the importance derived from this fact, and in consequence of the American war, passed, as it were, from the domains of the Physical Geographer, and entered those of the merchant, the political economist, and the statesman. But the question remains with the Physical Geographer, not to find new fields where cotton will grow,—for such are abundant,—but fields which, if planted with cotton, will best reward the labour of the husbandman. There are many parts of the world which are admirably adapted for the production of cotton, but more admirably adapted for something else, as grazing, the growth of coffee, cocoa, sugar, rice, tobacco, corn, the vine, the olive, indigo, tea, drugs, spices, ornamental woods, dye stuffs, cochineal, and the like. In these days, all people are wise enough to heed, in their chief industrial pursuits, those great laws of nature which regulate the geographical distribution of labour. The principal occupations of every nation and people are determined by the answer to the question: — which, of all the staples to which your climate and soil are adapted, will yield the most remunerative crops? Their knowledge of the principles of Physical Geography and of the markets generally, enables them to decide this question rightly. This brings us to consider the industrial pursuits of man as controlled by these principles.

§ 277. It is ordained that man shall eat bread 'in the sweat of his brow.' Let us, therefore, fully to appreciate the effect of climate upon the pursuits of man, take an extreme case for the sake of the illustration, and imagine a person set down at the Equator, and another at the North Pole, each compelled to seek bread in the sweat of his brow. He at the Equator, in gathering his food, would have but to stretch forth his hand and pluck and eat, for the climate there is so genial, and the soil so kind, that the earth will yield abundantly to the support of man for one day's labour in ten. The man in the Arctic regions, on the contrary, would find the climate so severe, and the soil so ungenerous, that he would be compelled to turn from the land and seek his food from the sea.

§ 278. Now, if we imagine representatives of the Arctic man gradually to extend themselves towards *the Equator*, and representatives of the equatorial man gradually to approach the Pole, until the two should meet on the parallel of 45° of north latitude,—midway between the Equator and the Pole;—and, if we observe the change in habit and modes of life in each set of representatives,—as, step by step, their descendants pushed forward their habitations, and approached this middle latitude,—we should discover that each family, accommodating itself to the new conditions imposed by the Physical Geography of its dwelling place, had departed more and more from the manner of life of its ancestors, whether they were established at the Equator or the Pole. The polar representatives, as they reach the more genial climates on their way south, would learn by experience gradually, as they passed parallel after parallel, to look less and less to the sea, more and more to the land, for a living. With the equatorial emigrants, the very reverse would be the case; for the farther they proceed towards the north, they would discover that the climates through which they had passed, had, when compared with the climate enjoyed by their equatorial ancestor, become less and less genial, the winters more severe, the earth less bountiful, and the conditions imposed by the Physical Geography of their new domicile, more and more exacting. Some, as they changed their skies, would be induced to the chase, others to the forest, others to the mine, and others to their rude workshops, and so on.

§ 279. You here discover, in this supposed case, all the natural elements and conditions which the Physical Geographer would prescribe for the largest commerce; namely, variety of production, diversity of occupation, with multiplicity of wants, real and imaginary. If all the world consumed only food and clothing, and if every family produced enough of these for its own use, there would be no barter, no trade, no commerce. Commerce, as just stated, depends, in a great measure, upon variety of production; and variety of production, in this aspect, implies diversity of climate with bountiful resources;—which assertion again brings us back to consider those physical conditions which chiefly control the industrial pursuits of man in the various countries of the world. Those of every civilised country are determined according to its natural resources and the facility of production. The planter within the tropics, who cultivates any of the staples there, as coffee, for instance, cannot trade with his neighbour, for each of them has nothing but coffee to sell, and each wishes to exchange his coffee for something the other has not, as meat, bread, clothes, luxuries, &c.

§ 280. The Mississippi river illustrates this view in a very striking manner. It runs from north to south, changing latitude and climate,—and therefore its Physical Geography,—with every bend it makes in its course. The consequence is, that the inhabitants of each city on its banks have need exactly of those articles of traffic which every other city, either above or below, has to spare. The result was, that the trade and traffic on the waters of this river had already, before the American war commenced, become more valuable than the entire commerce of the whole country with all the nations of the earth besides.

§ 281. It is in recognition of this principle that the discovery, by Vasco de Gama, of the passage around the Cape of Good Hope, was regarded as of so much consequence, and the commerce now carried on by this country with India is but the developement of the economical doctrines, which are to be learned from a *study of* our science, and from the application of its principles to the practical affairs of life. If the topographical features of the continents were equally favourable for the construction, in every direction, of works of internal improvement, as roads and canals, and if the natural resources between given parallels of latitude were the same, then it is obvious that grand trunk railways or main steam canals, running from north to south through the interior of continents, and extending up from the Equator to the frozen parallels of the North, with branches and feeders shooting out East and West, would best fulfil the requirements of commerce. The Mississippi river, with its tributaries falling into it from the right and left, is the natural type of what, in the supposed case, these great artificial lines for trade and traffic would be.

§ 282. The two great American rivers, the Mississippi and the Amazon, afford a striking contrast in this respect, and beautifully illustrate this doctrine. The one runs south; its trade is chiefly internal, consisting in the exchange of the productions of one littoral climate for another, and in collecting the surplus to be sent abroad. The other stream flows east; its tributaries run through little or no diversity of climate. Those who dwell in the valleys that are drained by them, cultivate pretty nearly the same staples; therefore the future Amazonians will perhaps never vie with the Mississippians in variety of produce, or in the amount of traffic, the one with the other.

§ 283. It is in homage to the proposition thus laid down (§ 281) by Physical Geography, and demonstrated by these two rivers, that the project of a ship canal across the Isthmus of Central America has never met with encouragement from enlightened governments. The Suez Canal, on the other hand, which aims to connect the Mediterranean with the Red Sea, is but an attempt to give practical expression to this principle, and to do homage to it by the payment of a tribute amounting to several millions sterling for the construction of that work. The Mediterranean, like the Amazon that flows east, is a long and narrow sea lying east and west. Unlike the Mississippi river, it lacks diversity of climate, and there is comparatively but little commerce in Mediterranean produce between the people who inhabit its shores. The sailing voyage from the ports of that sea, out into the Atlantic, and so to the markets of the world, is, on account of the westerly winds, Plate I., and the current (§ 221) setting into it through the Straits of Gibraltar, often tedious and difficult, sometimes requiring several months to accomplish.* The geographical position of England assisted her mightily to gain, and it is of incalculable advantage in enabling her to maintain, the commercial supremacy of all the world. Her islands curtain the western shores of Europe, and a ship as soon as it has cleared one of her ports, has already gained an offing with the wide ocean, the free winds of heaven, and the markets of the world, all before her. So that it not unfrequently happens that a ship can clear from Liverpool and double the Cape of Good Hope, before her rival from certain Mediterranean ports can clear the Straits of Gibraltar. Well therefore may the commercial people who inhabit the shores of the Mediterranean, watch with longings the progress of the Suez Canal, and wait with eager interest, its completion.

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* Maury's Sailing Directions; so also the Physical Geography of the Sea and its Meteorology, published by Sampson Low & Co., London.

§ 284. Returning now to our illustration (§ 278) as to the physical conditions which impose diversity of occupation upon the human family when in its uncivilised state, let us apply them to man in his present advanced state of civilisation. As the supposed representatives from the Equator and the Pole, reach the middle latitude, you would find each individual more and more at liberty to consult his own convenience or fancy, according to that station in life in which its chances or its accidents may have placed him, for neither set of representatives would find themselves constrained to look, the one exclusively to the sea or the other exclusively to the land, for the means of living. Some individuals or families, therefore, still preferring the sea, would stick to the sea; others to the forest or the field; and others again to the mines or the mills, the shop, the counting-house, and so on.

§ 285. Thus, in the progress of illustration, we reach what may be called those middle latitudes and climates of the earth which give rise to diversity of occupation, and present the greatest combination of commercial elements. England and France both lie within these latitudes, and, as we proceed from them, either to the north or the south, we approach the latitudes and climates which call more and more for simplicity of occupation and similarity of pursuit.

§ 286. The better to perceive this, consider the industrial pursuits of Egypt to the south of lat. 30°; then of Algeria between the parallels of 30° and 35°; then of Spain between 36° and 42°; then of France, England, &c., and so up to Norway and Sweden. You see in Egypt the people are, as they always have been, agricultural; in Norway, maritime; in Egypt, they gather into barns; in Norway, they extort from the sea: they are fishermen and mariners, and in olden times were, with the Danes, 'Sea Rovers.' Thus the commercial climates, where the multiplicity of human occupation reaches its culminating point, appear to be, in Europe, between the parallels of 40° and 60°;—in America, between those of 40° and 50°. The Gulf-stream and west winds make this difference.

§ 287. Man also, as he first began to increase and multiply, and to undertake the task of subduing the earth, proceeded to migrate, and spread his species in obedience to the laws of Physical Geography. Abel was a keeper of sheep, because there were green pastures in Mesopotamia. Tubal Cain a worker in metals, because of the minerals there. History tells us how civilised man within our own time has spread himself over the American continent. Let us see how far emigration there and the establishment of colonies have been in obedience to the principles of Physical Geography. In this examination we address ourselves chiefly to North America.

§ 288. It is not yet so long since the discovery of the New World by Columbus, but, by taking the oldest man now living in England, and supposing his ancestors to be equally long-lived, we can conceive that his grandfather might have conversed with the Great Discoverer, or some of his companions, so short is the time, in comparison with the age of the world.

§ 289. At the time of this discovery, though it was nearly 400 years ago, navigation was both dangerous and difficult. When the adventurous spirits which followed the early discoverers came back with the idea of returning to plant colonies or establish settlements, it was not enough to induce emigration by telling of the fine climates and fruitful lands of the New World.

Something more was needed to induce the yeomen and peasantry of the Old World to tempt the dangers of the sea, merely to cultivate the soil of the New. The bold men of that age, who put themselves at the head of every new expedition, returned to Europe with the most marvellous tales of mineral wealth, and physical wonders of the new country. The mind of all Europe was filled with the most extravagant and exciting stories, such as that of El Dorado, the gilded city of Manoa, where the houses were covered with plates of gold, and the streets were paved with precious stones. Expedition after expedition was got up to seek it out. Sir Walter Raleigh promised to pay his followers who went in search of his fabled mines of the Orinoco, not in sovereigns, but in patines of gold. Then there was the story of the Fountain of Youth in Florida, in which if a man but dipped himself, all the freshness and vigour of youth were restored to him again. Old Ponce de Leon, with a gallant band of followers, encountered many hardships and endured incredible sufferings in their vain search for this fountain. But all these expeditions had their advantages; they made known to Physical Geographers the natural resources of the country, and paved the way to settlement. The fabulous sums of gold and silver that were sent from Mexico and Peru appealed with eloquence irresistible to those who thirsted for adventure, or burned with longings soon to be rich.

§ 290. So the abundance of gold and silver, and the tales of the marvellous wealth of the New World, first set the tide of emigration fairly in motion towards America. It has continued until this day to flow stronger and stronger in that direction. It has been mainly directed to North America, partly from political causes, but chiefly in obedience to the principles of

Physical Geography and the dictates of commerce. We deal with the weights which Physical Geography has had in the matter, taking cognisance of the others only in so far as it may be necessary to vindicate the principles of our science.

§ 291. As is well known, this emigration has been chiefly to what *was* the United States. The contrast has often been drawn between the emigration thither and to Canada, in order to disparage the institutions of Canada and the enterprise of her people. With the exception of a few political malcontents and refugees, who fled from the Old World to the United States, the difference of 'institutions' between Canada and the United States, so far as the essentials of government and the liberty of the subject were concerned, had very little to do in turning the tide of emigration to the one country rather than to the other. I find an illustration of the correctness of this remark in the history of California and Australia. Here we have the same difference of 'institutions' that we have between Canada and the Northern tier of the American States. But we see that Physical Geography held out in Australia precisely the same golden influences that it did in California, and the rush to the gold fields of each was enormous. The emigrants to those countries paid no heed to 'political institutions.'

§ 292. The physico-geographical features of the country on the American side of the great Canadian lakes and rivers are quite different and far more attractive to the emigrant than are those of the British possessions. The tide of emigration was attracted by this difference. On the British side, the winters are longer and colder than they are on the Federal or American side. The consequence is, the climate is more trying to the emigrant, and it is far more difficult for him to get through the first Canadian winter, when his family, as a rule, is but indifferently housed at best, than it is on the American side, where the climate is not so severe nor the winter so long or so dreary.

§ 293. Nor is this all. The geographical features of the two regions of country are quite different, with the difference greatly in favour of the American side. In Canada, especially in Canada West, the forests are simply terrific, not so much for the size of their denizens as for their multitude. The trees there, throughout extensive regions, are so crowded together, and so thickly set in the earth, that the pioneer, instead of going as Daniel Boon went into Kentucky and Tennessee (§ 272), leaving the road to come after him, has first to cut and clear a road before he can enter the forest or form his settlement. On the Republican side, again, you have the boundless prairie stocked with buffalo, deer, elk, &c., and abounding in feathered game. Skirted with timber, these grassy plains afforded, without labour, excellent pasture the year round to the emigrant's cattle.

§ 294. Consequently, all the American emigrant had to do was to build a shelter for his family, put the plough into the ground, plant his crop of Indian corn, and his subsistence was secured. The Canadian, on the other hand, had first to fell the forest and clear a field in which he might stir the soil and plant his crop—plough he could not. The roots were so closely matted, and the stumps so thick, that the operation of ploughing was a difficult matter until time had been given for them to rot and the stumps to decay. And then his climate is not so well adapted to the indispensable and kindly Indian corn. The pioneer or 'backwoodsmen,' in countries adapted to the growth of this cereal, has no need of a mill to help him to bring the ripe grain into a culinary state. He simply roasts it in the fire, or boils it into 'hominy'—a dish of unground maize, as nutritious, as wholesome, and as palatable as bread. Simply to clear a farm in Canada, and get it ready for cultivation, costs about twelve times as much as the emigrant to America had to pay for his prairie farm, already cleared by Nature to his hand. In the open country, the rich lands and fine climates of Republican America, as compared with the British possessions on the North, the emigrant found mines of wealth that yield more abundantly even than the gold fields of California and Australia. In comparison with these mere geographical advantages, Nature holds out few to tempt him with equal force on the Canada side. The attractions of the gold fields in Australia and California were equal, and they operated alike upon emigration; indeed, the emigration from this country, and from Europe, was greater to Australia than it was to California, so little, in comparison with the natural resources of a country, has mere form of government to do with directing the tide of human emigration.

§ 295. The emigrant has been attracted to the Northern States by the rich and cheap lands there, which Nature has already prepared for the settler, and emigration will, it may reasonably be expected, continue to pour its myriads there in preference to Canada, until the 'institutions' on the American shores of the great lakes shall become intolerable, as they are likely to do, or until the good lands shall be all occupied, or held at such prices that the emigrant will find it cheaper to clear and subdue a farm in Canada than to buy one in 'the States.'

§ 296. Cuvier could, and Professor Owen of London

can, it is said, construct the likeness of any animal they have never seen, and draw a picture of it, if furnished with a single bone from its skeleton. And so may the Physical Geographer describe the main features and the climate of any unexplored country, if the traveller will only tell him of the beasts or the birds that he may have met with there. Did he see monkeys or parrots? then there were intertropical forests. Did he see beasts of prey —then there must be flocks and herds for them to prey upon: and flocks and herds require grassy plains and open spaces for pasturage. Therefore, when the geologist brings us from the caves or the gravel-pits of England and France, as he is continually doing, the fossil remains of deer, elk, and the like, or of other beasts, we know that France and England must, even in those remote ages, have had mountains clothed with forests, streams skirted with timber, as well as prairies or pampas, or whatever be the name by which the reader may choose to designate those treeless plains in nature, which everywhere, except in deserts, are covered with grass. Such, Nature, since the days of creation, has ever afforded in all countries as pastures for the graminivorous animals—as a refuge for the birds and a hiding-place for beasts of prey.

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